ELECTRIC POWER RESEARCH INSTITUTE

Radioactive Liquid Processing Guidelines

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Radioactive Liquid Processing Guidelines

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REPORT SUMMARY

This report presents guidance for utility liquid radwaste processing program managers. The document is a summation of utility and vendor processing experience, and is intended for use as a tool to enhance liquid radwaste processing programs. Utilization of this information will result in optimized system performance, and a reduction in waste volumes and program costs.

Background

Historically, utility liquid processing programs incorporated the use of original plant design processing systems augmented or replaced by vendor processing technology. More recently, utilities responded to the challenge of cost reduction by re-evaluating existing liquid radwaste programs and available alternatives, targeting process efficiency enhancements, and reducing associated program expenditures. In support of these efforts, EPRI undertook a project to assist utilities in improving the cost effectiveness of their liquid radwaste processing programs while simultaneously enhancing program performance.

EPRI published the previous version of the *Radioactive Liquid Processing Guidelines* (TR-107976) in 1997. Since then, the nuclear industry has developed several new technologies and strategies for treating liquid radwaste. Some of these technologies include ultrafiltration, chemical polymer injection, and novel applications of granular activated carbon. The new technologies have often improved the performance of the liquid radwaste systems; however, there have been operational issues and concerns that required considerable effort to ensure consistent operation. This document collects the experiences obtained from utilities using these technologies, and communicates the advantages and caveats to our members.

Objective

To identify liquid radwaste process technologies, methodologies, recommendations and experiences to optimize liquid processing programs.

Approach

A team of utility liquid processing professionals, EPRI, and technical consultants identified factors impacting liquid radwaste processing performance, volumes, and costs. The team also evaluated techniques and cost factors related to disposal of the resultant solid waste. The researchers performed an extensive review of past, present, and proposed processing technologies; their effectiveness and associated costs; and plant processing experiences and techniques. They also identified and incorporated the optimum process program components into this document. This report is a compilation of the analysis, which EPRI intends to provide guidance to liquid radwaste processing program managers to enhance overall program performance.

Results

This document presents numerous guidance elements that managers can implement to improve processing program performance and achieve significant cost reductions. The report includes an introduction and project overview; an executive summary describing the major components of a successful program; and specific program guidance. The guidance elements identify processing program components eligible for improvement; and give specific guidance for improvement. The document also describes expected results of successful implementation. Many of the guidance elements have the potential to result in tangible cost savings for utilities.

EPRI Perspective

As utilities continually strive to maintain their positions in a competitive market place, modifications which result in improved processing efficiency and reduced operating expenditures will become more critical. Utilities can reduce the costs associated with radioactive liquid processing through improved program management without large capital expenditure. This report offers processing performance improvement and cost reduction oriented program enhancements based on actual plant experience and available technology.

Keywords

Low level radioactive waste management
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"Our experience at Comanche Peak clearly demonstrates that similar to an ALARA program, strong visible management support of our Liquid Processing Program is critical for achieving optimum plant staff participation. Without that support, liquid processing program performance remains a departmental issue. With it, the performance becomes a site priority."

Lance Terry
Group Vice President of Nuclear Production
Comanche Peak Steam Electric Station

1.1 Background

Historically, utility liquid processing programs have incorporated the use of original plant design processing systems augmented or replaced by vendor processing technology. In the past decade, many revisions to industry regulations and available options related to power generation, distribution and radioactive waste processing and disposal have resulted in a need for utilities to become even more cost efficient. In many cases, radwaste processing and disposal costs can be a significant portion of the overall station Operation and Maintenance (O&M) budget.

As a result of these issues, radwaste program managers are challenged by the need to provide a necessary service to the station in compliance with stringent regulations, while simultaneously reducing O&M costs. They have responded to this challenge by re-evaluating existing liquid radwaste (LRW) programs and available alternatives, targeting process efficiency enhancements and reductions in associated program expenditures.

In support of this effort, EPRI undertook a project to assist utilities with improvements to processing programs. The project targeted program cost effectiveness while simultaneously optimizing process performance. It included a detailed review of utility and vendor process experience, technology, methodologies, and industry lessons learned. This guidance document is a product of that project. It identifies specific program cost reduction and process performance enhancements.

1.2 Successful Program Management

Industry experience has repeatedly confirmed that the leading LRW processing programs achieve success only with the support of senior station management. The most successful liquid processing program managers are diligent in obtaining and maintaining site support of radwaste goals. This task can be complicated by perceived conflicts between processing and other established, well understood goals. In 2003 EPRI released an industry document titled

"Strategies for Managing Liquid Effluents – Options, Actions and Results" TR-1008015. That document is designed to assist program managers with defining an optimal, balanced liquid effluent strategy.

Liquid waste processing programs do not normally impact capacity factor or plant reliability. Therefore, processing issues may be assigned a less than ideal priority relative to the cost benefit associated with their resolution. A liquid radwaste processing program can have a significant impact on station O&M costs. While annual liquid radwaste processing program costs can easily range from one to several million dollars, the associated fixed labor costs are typically less than 50% of that amount. As a result, program enhancements in this area can result in significant, tangible savings to the utility. Also, improvements to liquid processing programs often impact programs and resources external to the lead processing organization. Therefore, those improvements need to be carefully assessed to ensure cost savings realized by those organizations are captured. This process can take several years to fully implement the enhancement, identify all cost elements, and realize quantifiable savings. The station should consider this time frame when assessing the cost benefit of an improvement.

Further complicating management of liquid radwaste processing programs is the "invisible" nature of the process. Liquid radwaste is generated and routed to treatment processes that are not normally accessed by the balance of the plant staff. This creates an artificial barrier between the person generating the liquid and the end result – processing media impact, solid waste generation and its subsequent disposal. This produces a challenging environment for program managers to effectively communicate the impact of liquid waste improvements to external organizations. The Radwaste organization possesses the technical expertise and equipment to process waste liquid once generated, but cannot control all inputs generated by external site organizations. Clearly defined **station** expectations that are effectively communicated by senior station management to the plant staff will help the station achieve the desired Radwaste program goals.

1.3 "The Best" Program Attributes and Benefits

1.3.1 Program Attributes

The definition of a "successful" program varies between utilities. Regulatory compliance is the primary goal for all utilities and is a **non-negotiable component** of a successful program. The following attributes represent the elements or goals associated with an ideal liquid processing program. They were derived from actual plant experiences related to successes and lessons learned from failures. It is critical that a successful station's program performance be carefully measured using all, or combinations of, the following:

- Comprehensive system performance monitoring program.
- Comprehensive outage water management.
  - Radwaste involvement in pre-planning and execution.
  - Integrated, formalized water management schedule.
- Accurate accounting of total liquid and solid wet program costs.

- Media management.
- Multi-discipline labor.
- Site-wide, impacted O&M costs.
- Volume reduction and disposal.

- Positive control of liquid process system(s) influent.
  - Volume reduction (aggressive leak reduction, publicized goals).
  - Quality of waste inputs.
- Active Chemistry involvement.
  - Routine chemical characterization of process.
  - Decision making input.
  - On-going communication.
- Radionuclide source term reduction.
- Commitment of justified capital expenditures to attain significant program improvement.
- Adequate resources to evaluate emerging cost effective technologies.
- Liquid processing program continuous improvement.
  - Active, aggressive task force.
  - Benchmarking.
- Aggressive materiel condition improvement for systems impacting liquid radwaste processing.
  - Fix-It-Now Team.
  - Priority based on impact.

1.3.2 Derived Benefit

The specific benefit to a station will vary by application and period of performance. Stations that successfully implement and integrate the above attributes will realize significant, tangible program benefits. Those benefits may include, but are not limited to, the following:

- Positive position with industry organizations (USNRC, INPO, ANI, EPRI, NEI, state and local regulatory agencies).
- Balanced effluents program with minimal environmental impact.
  - Off-site dose.
  - Activity.
  - Chemistry (NPDES)
- Reduced outage duration.

- Low program O&M costs.
- Minimized solid radioactive waste generation.
- Optimization of labor support requirements.
- A continually improving liquid processing program.
- Reduced curies.
  - Released.
  - Personnel exposure.
  - Disposed.
- Reduced impact on site decommissioning impact.

Historically, the industry has used effluent activity and/or solid waste disposed as the principle performance indicators. These indicators are important; however, they are not the only elements of a successful program. Their sole use can result in an under appreciation of the impact of other indicators (elements) associated with a cost effective program.

INDUSTRY EXPERIENCE: At one station, Maintenance related system draining frequently resulted in routing of undesirable waste streams to the liquid radwaste processing system. This resulted in a reduced media life, increased waste disposal costs, exposure and labor requirements. An inter-departmental team analyzed draining practices and identified improvements. That plan resulted in media procurement savings for the Chemistry department and reduced personnel exposure. The Operations organization realized reduced demands related to media transfer, maintenance support planning, and equipment isolation and draining. The Radwaste organization significantly reduced solid waste packaging, transportation and disposal costs.

1.4 Program Direction and Focus

The program attributes presented above, while individually important, must be balanced when combined or they can result in conflicts when evaluating liquid waste processing strategies. For example, reducing processing system effluent activity may require more on-site exposure related to processing and packaging, and may increase program costs. Similarly, processing low quality liquid waste streams for recycle in an effort to reduce the effluent release volume to as low as is reasonably achievable, could significantly increase program costs, solid radwaste volumes, and on-site worker exposure, and can eliminate needed processing flexibility.

The following figure illustrates the issues station management needs to carefully weigh and balance to achieve program success.

Figure 1-1
Balancing the Elements of a Successful Program

For those programs that are successful, senior management's level of effort is significant in that it provides focus and direction related to the desired program endpoint. Middle and low level managers need to receive educated, clear **and achievable** direction related to benchmarking and program expectations.

1.5 Report Organization

Section 2 provides program management guidance. Sections 2 through 7 contain detailed discussion related to program elements, additional guidance for successful liquid waste program management, and specific recommendations for use by utility radwaste program managers. Appendices A through D present applicable reference documents, a specific improvement index applicable to this report, example data tracking and trending concepts, and processing system selection examples.

1.6 Recommended Report Use

When utilizing the industry experience and guidance included in this document, the program manager should ***ensure any proposed changes are thoroughly analyzed. The evaluation should verify:***

- Compliance with regulations and licensing documents.
- Cost effectiveness.
- Process applicability (correct application for that technology).
- Process compatibility with station process streams, structural constraints and equipment.

In addition to the preceding, the utility should carefully evaluate all factors associated with a technology or processing methodology prior to selection and implementation. When analyzing cost effectiveness, the manager should ensure the utility's goals and long range plans for liquid processing and waste disposal are known, match the expected benefit to be derived, and are incorporated into the analysis. It is also imperative that the user of this report has a thorough understanding of available in-plant liquid and waste processing systems.

After carefully reviewing this report, it is recommended that the station identify its top priorities and associated goals. Resources should then be focused on implementation of targeted improvements. The utility should carefully evaluate the system/component performance prior to, during, and following implementation to ensure it is optimal and to provide data for future improvements. Following successful demonstration of those changes, a continuous improvement plan should be followed that incorporates other applicable, prioritized program enhancements.

Much of the guidance provided in this document directly impacts, or is directly impacted by, other station organizations. To ensure successful and continuous program improvement, those organizations should be involved in proposed changes to the program from inception of planning and implementation efforts. This will help to establish "ownership", and hence support, from those organizations required for continued program success.

It is equally important to carefully assess improvement inception-to-implementation scheduling relative to the projected cost benefit. Delays related to planning and execution of improvements will diminish the overall savings achieved.

NOTE: The words "routine" and "routinely" are used throughout this document to define frequencies or typical occurrences. This document is not intended to define individual "norms", but rather to establish the realization that routines are required to effectively manage the program. The time definition associated with routines will vary from station to station and by application in this report. It typically means weekly or less, prior to or immediately following a change in status, or when deemed necessary to successfully support the guidance provided. Its broad definition is meant to establish a **practice** of performing that guidance to further enhance program success and support for plant goals.

2
PROGRAM MANAGEMENT

2.1 Overview

Successful management of a liquid processing program encompasses an array of responsibilities and also requires knowledge of numerous program elements. Support is required from site organizations external to the processing program manager as well as from other industry organizations. The site staff must be educated on aspects of the program that affect them and conversely, that they can impact. Program costs and performance need to be closely monitored to ensure process performance is optimal and the program is cost effective. Self assessments combined with industry agency evaluations/inspections should be used to benchmark program performance and also to assist in developing improvement plans. In 2003 EPRI released an industry document titled "*Strategies for Managing Liquid Effluents – Options, Actions and Results*" TR-1008015. That document is intended to assist program managers with defining an optimal, balanced liquid effluent strategy. Its use in conjunction with this document is highly recommended.

This section provides guidance on key management elements of a liquid processing program. It is intended to serve as the foundation for successful management of a process program.

2.2 Program Element: Goals

2.2.1 Program Impact

Goals and objectives provide challenge, focus, and overall direction for any organization. Radwaste goals are often relegated to a less visible status when compared to other primary station goals such as those related to capacity factor or the as low as reasonably achievable (ALARA) concept. How goals are communicated or perceived by the plant staff directly impacts the station's ability to meet those goals. Achieving goals is directly influenced by visible management support; it should be ***present and apparent*** to the plant staff.

The goals, while individually important, are confusing when combined and create conflicts when evaluating liquid waste processing strategies. For example, reducing processing system effluent activity may require more on-site exposure related to processing and packaging, and may increase program costs. Similarly, processing low quality liquid waste streams for recycle in an effort to reduce the effluent release volume to as low as is reasonably achievable, could significantly increase program costs, solid radwaste volumes, and on-site worker exposure, and can adversely impact processing flexibility.

CAUTION: Recycle of water that has not been totally segregated from low quality collection system drains (e.g., floor drain, laundry) or has been transferred through piping, sumps and tanks that have contained them can return difficult to detect organics or other chemical contaminants to Reactor Coolant system. This may adversely the reactor coolant system quality.

INDUSTRY EXPERIENCE: One station uses Fix It Now team performance indicators to monitor the health of LRW systems and RCA leakage. This has proven to be very effective at reducing liquid volumes, improve influent quality, and process system performance.

The Radwaste organization possesses the technical expertise and equipment to process waste liquid once generated, but cannot control all inputs generated by external site organizations. Clearly defined and communicated processing program goals will help them achieve the desired endpoint.

2.2.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Establish station goals associated with liquid waste processing that are related to effluent activity and processing media throughput in gallons processed per cubic foot of media. In addition to these goals, a station typically should have goals associated with:
   - Program cost.
   - Liquid waste generation volumes.
   - Solid waste generation resulting from processing radioactive liquids.
   - On-site worker exposure.
   - Off-site exposure.
2. Communicate goals in a language the entire site staff can understand (e.g., create a goal the people that impact that goal can visualize). Goals are established to motivate the staff, not to generate reports.
3. Develop a station liquid generation goal in gallons per day (gpd) for LRW. The goal should be shared by those departments responsible for liquid waste generation.

NOTE: The Radwaste organization possesses the technical expertise and equipment to process waste liquid once generated, but cannot control all inputs generated by external site organizations. Clearly defined goals will help them achieve the desired endpoint.

INDUSTRY EXPERIENCE: Can the staff comprehend the impact of a 0.7 gallon per minute (gpm) leak? The use of gallons per day (gpd) versus gpm will result in a more dramatic and meaningful portrait for the plant staff and help to focus the appropriate amount of attention on the leak rate. A 0.7 gpm leak rate equals a TOTAL leak rate of ~1,000 gpd. The plant staff that reviews and uses the data would probably be more concerned about a source of leakage that produced over 1,000 gallons of liquid every day than they might be for a leak that produces only 0.7 gpm.

4. Ensure that goals related to station performance are recognized as tools for monitoring station performance relative to waste generation, rather than as Radwaste organization proficiency indicators.

5. Develop goals that do not conflict with each other. A zero liquid volume release plant cannot achieve a goal of zero process media solid waste generation. Similarly, achieving zero liquid release may increase program costs and site exposure. The EPRI report titled “Strategies for Managing Liquid Effluents – Options, Actions and Results” TR 1008015 is useful when defining optimal, balanced goals.

6. Communicate the goal to the plant staff and increase the staff’s awareness relative to the costs associated with LRW processing, packaging, and spent media processing and disposal. Focus initial educational efforts on the organizations that have the largest impact on the LRW volumes. As a minimum, these should include all operations and maintenance personnel.

Cross Reference(s):

1. None

2.3 Program Element: Tracking, Trending and Reporting

2.3.1 Program Impact

Tracking, trending, and continually evaluating program performance can provide valuable information for program management. The data can be used for:

- Ensuring compliance with regulatory requirements.
- Monitoring a processing system's or a single component’s performance relative to established goals.
- Identifying, planning, and implementing LRW processing improvements.

- Program cost analysis.
- Problem identification.
- Abnormal leak rate identification and analysis.
- Modification evaluation.

Most utilities track and trend portions of the pertinent program data, such as liquid waste generation and resultant solid waste volume. However much of the readily available chemistry and processing data are typically not fully utilized (e.g., individual processing systems and component's decontamination factors (DF) are not tracked on a routine basis). At the more successful stations, the existing data review process allows for a timely, detailed system performance evaluation, and subsequent processing configuration adjustments.

> **INDUSTRY EXPERIENCE**: One BWR station developed a spreadsheet (Waterboy) for volumetric tracking. This tool addresses all sump and tank levels, accounting for plant input and output volumes, including makeup and releases. It is used by the site to perform a daily plant-wide water balance. The results are used when assessing evaporation and leakage losses.

The benefits of tracking, trending, and evaluating processing data include:

- Proactive, rather than reactive program management.
- Continuous and consistent program analysis.
- Lower system effluent activity or dose.
- Better use of processing media.
- Timely correction of system deficiencies.
- Generation of less liquid and solid radwaste.
- Timely and correct feedback to station personnel.
- Reduced O&M expenditures.

EPRI's Waste Logic™ Liquid System Multi Site Manager (LSMSM), is slated for publication in December 2006. This program is an outgrowth of the Fast Track liquid process data management, and Liquid Waste Manager liquid process cost analysis programs. LSMSM is a database for tracking and trending critical liquid processing performance and cost data at both the site and corporate level. The code can be directly linked to plant chemistry and operational databases for automated data entry. The program contains a financial analyzer for assessing process related costs and for evaluating the cost efficiency of proposed program revisions.

2.3.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Establish a formal plan to routinely analyze, track, and trend the LRW system performance. Some of the key areas to evaluate include:
   - Sources of liquid waste.
   - Individual system and/or component's influent and effluent chemistry and activity characteristics.
   - System performance (i.e., weighted DF, gallons per ft^3 of media, etc.).

   Note: For units having minimal influent volume and activity, the use of absolute concentrations may be more indicative of media or process performance than DFs

   - Costs for all aspects of liquid processing.
   - Solid waste volumes generated from liquid waste processing.
   - Performance relative to established station goals and the industry (i.e., activity, dose).

Key Consideration:

A weighted DF calculation defines the volume of liquid processed by a known volume of media in gallons per cubic foot. This calculation is useful for evaluating performance and for identifying opportunities for improving influent water quality, changing media types, or altering process or component configurations. The calculation is performed as follows:

1. Calculate individual DFs based on a matched influent and effluent sample data set; divide the influent activity (A) by the effluent activity (B).
2. Multiply each Individual Set DF by Gallons Processed (C) for that data set to obtain the Derived Value.
3. Add all Gallons Processed for the same user defined period of time (e.g., last 24 hours, week, etc.) to obtain Total Gallons.
4. Add all Derived Values for the user defined period of time to obtain Sum of Derived Values.
5. Divide Sum of Derived Values by Total Gallons to determine the Weighted DF.

Sample Set	Influent Activity (A)	Effluent Activity (B)	Individual Set DF	Gallons Processed (C)	Derived Value [(A/B)*C]
1	0.06	0.006	10	10,000	100,000
2	0.03	0.0005	60	5,000	300,000
3	0.05	0.00005	1000	7,000	7,000,000
			Total Gallons	22,000	
				Sum of Derived Values	7,400,000
				Weighted DF	**336**

2. Use of the EPRI Waste Logic™ programs to capture, track, and trend live processing data and for defining accurate processing program costs.

3. Use the program output to define baseline performance and cost efficiencies, and to identify opportunities for improvement.

4. Track and trend data that can be used to supplement and more easily verify station progress and station improvements. These data is useful during reviews by various regulators and industry organizations, and can provide additional information for the required annual reports (i.e., environmental and effluent discharge). Trending these data may also help to validate that the plant is being operated within its design basis.

INDUSTRY EXPERIENCE: Radwaste sump runtime data was tracked and trended and was subsequently used to verify that observed leakage from a Safety Injection valve was within the loss of coolant accident (LOCA) design calculation.

5. As a minimum, establish a formal routine for periodic review of process parameters. It should include personnel such as the chemistry liquid process expert, process system operator and/or supervisor, system engineer and system manager.

2.3.3 Cross Reference(s):

1. EPRI. Waste Logic™ Liquid Waste Manager. CM-1002760

2. EPRI. Waste Logic™ Fast Track. CM-1009563

2.4 Program Element: Benchmarking and Self Assessment

2.4.1 Program Impact

Evaluating a liquid processing program and comparing the program performance to other stations can be a useful exercise. Numerous industry organizations including EPRI, ANI, INPO, USNRC, and NEI utilize performance data for specific program areas. Currently liquid effluent (release) activity and volume are the primary indicators in use by the majority of organizations. The data is generated as a result of the USNRC Regulatory Guide 1.21 reporting requirements. In addition, EPRI has developed the RadBench liquid and solid radwaste processing data capture and trending Website. That database collates data that can be used for program performance evaluation relative to other stations, as well as for assessment of vendor performance.

Additionally, there are a host of industry educational and information sharing forums targeting industry concerns and the status of technological advances. Those forums have been instrumental in supporting the positive processing and effluents trend the industry is currently experiencing; this is due to their direct contribution to specific program problem resolution, and/or the generation of new ideas that result in technological advances for the processing industry.

Process performance and cost information can be obtained in several different ways including the following:

- Assessments and evaluations performed by the organization.
- Periodic industry organization reports.
- Meeting attendance.
- Newsletters.
- Vendor processing performance reports.
- Electronic mail.

Another and similarly effective method of benchmarking program performance is by direct contact with industry peers. This provides an opportunity to obtain current data, discuss data anomalies, and potentially share solutions to specific program problems.

In conjunction with benchmarking, critical self assessments are an especially useful tool for ensuring optimal program performance and for verification of compliance with station and industry organization's expectations and regulations. Internal Quality Assurance audits performed using a proceduralized checklist can provide performance trending data for comparison to previous performance. Self assessments are also an excellent method of soliciting feedback from the balance of plant staff related to the impact of the process program and proposed changes.

CAUTION: The quality and clarity of the criteria used combined with the evaluator's experience are critical to the success of the previously discussed benchmark options.

2.4.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. When using data provided by industry organizations for program comparison or evaluation, it is extremely important to ensure the data is collated, analyzed and presented in equitable terms. The benchmark data should be clarified to account for differences in liquid processing options deployed (such as demineralizers or membrane), and process stream volumes and characteristics. Verify generated, released and disposed data are segregated for accurate volume comparisons.

> **CAUTION:** Regarding evaluating benchmark data; Plant data surveys typically rely on individual interpretation of the data request format. As such, data related to volumes generated, processed, packaged, shipped, disposed, or stored may be misinterpreted as a result of plant specific definitions, processing systems in use, vendor data, units, reporting periods, etc. The result may cause inaccurate and unrealistic expectations related to perceived plant performance when compared to other stations.
>
> The majority of US stations input processing data to the EPRI RadBench Website [www.epriwastelogic.com/radbench]. That site's collective data are available to EPRI members and provides relatively accurate, normalized industry performance and cost benchmark information.

2. Obtain accurate plant data via direct contact with peers at stations with similar processing configurations and inputs. The EPRI Waste Logic™ performance and cost programs provide a platform for consistent, accurate plant, utility, and industry benchmarking.

3. A list of carefully considered site or issue specific questions can produce accurate data for comparison or evaluation. The use of industry reference documents such as this and other liquid processing and effluent references is useful when developing concise and comprehensive questions.

4. Performance of self assessments on a scheduled, periodic frequency. It is important that the assessor have a fundamental understanding of the process methodology and technology. The quality and clarity of assessment criteria should support a detailed, accurate evaluation. Typically, the more knowledgeable the assessor, the more beneficial the assessment. To prevent biased results, it is equally important that the assessor not be directly associated with the processing program.

5. Solicit feedback from plant organizations impacted by the liquid processing program, specific liquid processing support organizations and senior plant management. Review and analysis of honest feedback can often be an enlightening experience resulting in changes that create improved "ownership" and support from organizations external to the liquid processing program.

2.4.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

2. EPRI RadBench Website. www.epriwastelogic.com/radbench

2.5 Program Element: Ownership and Empowerment

2.5.1 Program Impact

Teams and task forces can achieve impressive results and are an excellent communication forum, but require controls and diligent oversight to ensure parallel tasks are not negatively impacted. Liquid radwaste processing is a multi-disciplined program and requires **commitment** from other station organizations. Teams have proven to be very effective for implementing major changes such as advanced equipment installation, or improving liquid processing system influent quality. They can produce a "Win-Win" situation by resolving issues related to one organization, such as Operations or Chemistry, while simultaneously improving radwaste processing program performance.

Several utilities have successfully used the team concept for resolution of issues ranging from repair of minor equipment deficiencies to complex radwaste process technique or equipment modifications. The results have been achieved as a result of communication definition, communication effort minimization, and productivity maximization.

> **INDUSTRY EXPERIENCE:** At one utility the original plant design resulted in closed cooling water being drained to the radwaste system. Because this system contains a corrosion inhibitor that prematurely exhausts ion exchange media, a practice of verifying that no radioactivity was present before draining to a non radioactive sump was established. Unfortunately this necessitated draining via two 1 inch lines and was a time consuming process. With the desire to shorten outage duration, Operations wanted to return to the original design. A team of two (Chemistry and Operations) came up with a compromise that allowed the system to be drained quickly and yet still be drained to the non-radioactive sump.

Similar to program ownership, ownership by the equipment operators is equally important. The most successful stations employ a dedicated crew to operate LRW processing equipment. This provides several benefits including:

- Improved process knowledge and proficiency.
- Improved shift turnovers supported by the knowledge level and program ownership.
- Ownership of the materiel condition and performance results.
- Development of system experts that can assist with troubleshooting, maintenance, and engineering efforts.

These benefits indirectly result in improved system performance, improved effluent quality and reduced media generation requiring VR and disposal. The combined effect can result in significant savings to the station related to media procurement, waste VR and disposal, reduced ANI premiums, and reduced maintenance requirements.

2.5.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Establish a processing improvement team.
   - The goals of the team should be clearly defined as soon as possible.
2. Schedule meetings in advance and in consideration of participant's collateral responsibilities.
3. The roles and responsibilities of team members should be defined to all team/task force members. A team leader/mediator with overall responsibility is a must.
4. Tie-in targeted improvements to goals for those organizations that are impacted by or impact the improvement. For example, successfully achieving challenging goals related to housekeeping or leak reduction can result in improvements to the liquid radwaste processing program.
5. Team involvement should require minimal paperwork. Minimize administrative demands on team members and the team leader.
6. Focus on action items, prioritization, solutions and schedules.

2.5.3 Cross Reference(s):

None

2.6 Program Element: Cost Analysis

2.6.1 Program Impact

Processing cost analyses can be useful when evaluating the significance of a waste stream, the current costs when comparing alternative processing strategies, as well as the impact of waste generation on the station's O&M budget (i.e., when attempting to heighten station awareness relative to liquid waste minimization). The calculated data can also be used for justifying repairs and/or equipment replacement. There are numerous cost elements to be considered in the analysis including the following:

- Processing system operational labor (loaded rates including benefits).
- Processing media.
- New media handling and warehousing.
- Spent media changeout/transfers.
- Resultant waste volume reduction (VR).

- Resultant waste packaging.
- Resultant waste disposal and/or storage.
- Annualized system upgrade costs.
- Program management.
- Processing configurations and alternatives.
- Equipment repairs and preventative maintenance (PM).

2.6.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

> **KEY CONSIDERATION:**
> An individual station's processing cost-per-gallon typically accounts for varying combinations of program elements such as labor, media, packaging, shipping, disposal, etc. Therefore it is recommended that both fixed and variable cost elements be clearly defined prior to benchmarking station cost performance.

1. Calculate program costs on a routine basis or whenever program cost elements are known or expected to change. A useful calculation unit is cost-per-gallon for all liquid waste processing. This cost unit is especially useful when educating the balance of the plant staff on LRW minimization issues.

2. Use the EPRI Waste Logic™ cost analysis programs to develop a detailed site specific economic and performance model for liquid processing systems and activities. The analysis should include labor and materials costs associated with treatment processes, waste packaging, volume reduction, transportation, and disposal. The analysis should also be used to analyze the costs and basic performance parameters associated with program enhancements and anomalies that have the potential to impact processing costs.

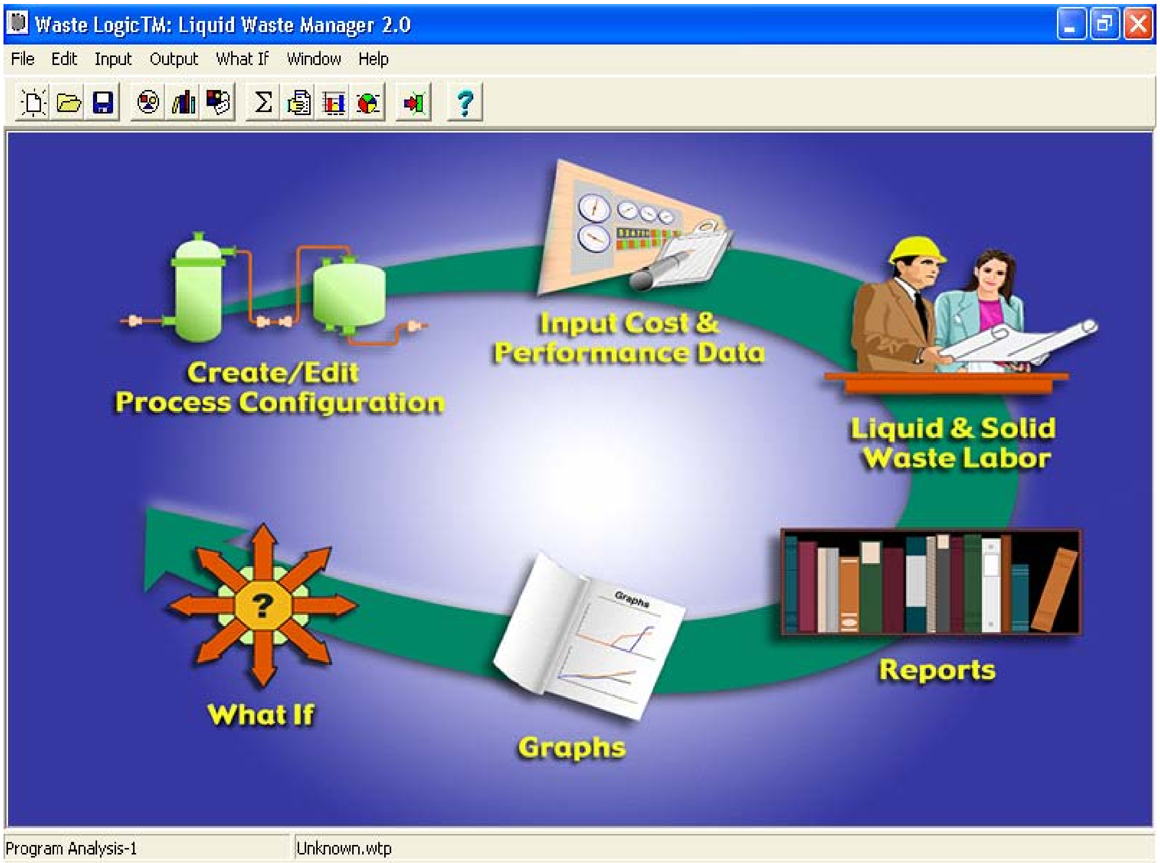

Figure 2-1
EPRI Waste Logic™

Table 2-1
EPRI Waste Logic™ Results

Component	Cost Per Liquid Volume Processed	Cost Per Volume Of Solid Waste Generated	Cost Per Volume Of Solid Waste Disposed	Total Costs
	$/gal	$/ft3	$/ft3	$
LRW Filter OF 302 A	0.02	2,075.71	1,724.53	262,577.20
LRW Filter OF 302 B	< 0.01	1,952.98	1,622.56	78,119.01
LRW Demineralizer OF 301	0.03	628.32	6,918.99	502,655.30
System Capital and Other O&M Costs	0.00	0.00	0.00	0.00
System Operation Labor	0.06	935.25	3,310.42	903,922.60
Vendor Liquid Process Fee	0.00	0.00	0.00	0.00
System Total	0.12	1,807.84	6,399.00	1,747,274.00

3. Perform a total cost analysis routinely or when any cost factor changes. That value should then be compared to the program cost-per-gallon.

2.6.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. Waste Logic™ Liquid Waste Manager. CM-1002760

3. EPRI. Waste Logic™ Fast Track. CM-1009563

4. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

2.7 Program Element: Station Awareness

2.7.1 Program Impact

The communication of a liquid processing program's status to the plant staff is important. It can increase their awareness relative to the costs associated with radwaste generation, processing, packaging, and disposition. Several methods for increasing station awareness include senior management communiqués, training, posters, and written and verbal program updates.

Many utilities use internal webpages to communicate program performance. This option requires access to computers by 100% of the target audience.

For the balance of plant staff, remote monitors (screens) and posters can be an effective form of communication. It is important balance the volume and clarity of the content relative to the benefit derived to ensure the information remains of interest to the target audience. Strategic wording and poster placement can help to ensure that the posters will result in the desired message being conveyed to the staff. They are also an excellent medium for communicating through the use of photographs, computer generated graphics or artwork. They should illustrate not only what is good, but also what is an unacceptable radwaste condition or status.

2.7.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Verbal or written communications can effectively communicate program goals, status and issues. Initial educational efforts should be focused on the organizations that have the largest impact on the LRW volumes. These organizations typically include operations, planning and maintenance.

2. Several stations have developed detailed chemistry performance tracking programs that can be accessed by non-chemistry station personnel for information only. This is an excellent technique for disseminating information related to radwaste chemistry data.

3. Design a basic liquid processing information bulletin for distribution by electronic mail or remote broadcast monitor. When designing the routine communication or plant accessible data program, consider the following guidelines.
   – Access and use the plan of the day or daily newsletter to transmit general interest or unique items to the entire plant staff. This will help to maintain a “radwaste presence”.
   – Several utilities use monitors mounted in key areas of the plant to broadcast closed loop communications that are modified daily. Including radwaste topics of interest in this type of communication significantly increases the audience size and profile.
   – Define the target audience and develop a master template for data input and transmission. This will reduce the routine workload.
   – Query the recipients and based on feedback, revise the template as appropriate to accommodate the end user. Remember the goal is to educate the recipient, not the system experts.
   – When developing a radwaste database for information access by non-radwaste personnel, ensure headings, units and data are clearly understood by the target audience (those other than the database development team). This will increase the likelihood that the information will be beneficial.
   – For routinely issued communications, only provide the necessary information - don’t transmit an entire database. Minimizing the volume and improving the clarity and layout of shared information will result in increased use by the target audience and will minimize the number of clarification queries.

4. Develop a few posters that clearly illustrate the targeted issue (in the correct audience “language”). The posters should have clear, concise messages with a minimum of background clutter. Locate posters where they are not in conflict with other messages such as those for security and fire protection. It is important to ensure the location doesn’t compromise the ALARA concept or worker safety (i.e., in stairwells or near doors).

5. Develop Operator aides for controlling processing system liquid inputs and system/component drain path selection.

6. Implement a ‘report card’ for waste generators. This concept provides an organization specific summary of generated liquid volumes, input quality, and their impact on solid waste volume, cost, and/or exposure. This is provided and/or presented to the “actual” waste generator department head on a periodic basis.

2.7.3 Cross Reference(s):

None

2.8 Program Element: Training

2.8.1 Program Impact

Radwaste related training is an excellent and relatively inexpensive vehicle for improving program performance. It often can be accomplished in conjunction with training required for continued plant operation. General access or radiation safety training is fine for generic topics, but typically workers are inundated with information during those sessions, and the effectiveness of including important radwaste issues may be compromised.

In an effort to continually improve plant processes, workers are given significant amounts of training related to job specific performance and numerous other issues important to successful plant operation. However, these training sessions do not normally provide for routine refresher training related to radioactive waste processing. This limits the ability of a Radwaste organization to improve their overall program. Additionally, by default, this can result in the plant staff assuming that radwaste processing is not an important or costly aspect of plant operations.

The technical and reference information developed for training should also be structured and documented to create a ready resource that can be used for educating future generations of process owners. This supports industry succession planning, offsetting the loss of experienced staff members and their undocumented in-depth process knowledge.

Additionally, training should be developed for vendor supplied systems regardless of whether they are operated by the plant staff **or** the vendor staff. At a minimum, the curriculum provides the plant staff with the requisite knowledge to successfully support that process.

2.8.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Develop radwaste task specific training for the radwaste/liquid processing staff. As part of that training, include an information “hotline” phone number and key waste issues.
   - Ensure the training clearly defines responsibilities as well as how individual performance impacts program success.
   - Provide the training on a routine basis and most importantly, prior to process changes in the plant (i.e., prior to outages).
   - Update lesson plans frequently to ensure the classroom information exchange is accurate and timely. Include outage impact as part of that update and exchange.
   - The most successful programs include the actual processing system operators and chemistry personnel in the development of training curriculums.

2. Incorporate mobile or alternate system operator training and qualification in plant procedures and processes.
   - For vendor staff operation: develop training for the operator and for the plant support staff to ensure their knowledge of the process is adequate to support successful operation.
   - For plant staff operation: develop training that includes an in depth review of the process technology.
3. Include a brief radwaste processing topic in each of the trade-specific training programs.
   - This can be established as an integral part of routine training, or can be effectively presented as a stand-alone presentation by Radwaste management.
   - Several utilities have successfully developed 15 minute to 1 hour radwaste training modules for inclusion with routinely scheduled trade specific training.
   - Positive reinforcement videos are used at several utilities as a successful means of communication without increasing the instructor workload, and they can be designed and used for a broad spectrum of audiences.
   - A brief radwaste specific module, to be given to a mechanic in conjunction with a pump rebuild class, is relatively easy to develop and can result in large dividends for the radwaste organization.
4. Incorporate articles related to radwaste program successes or lessons learned from failures, as a routine feature in daily, weekly and monthly newsletters.

2.8.3 Cross Reference(s):

None

2.9 Program Element: Operational Planning

2.9.1 Program Impact

Routine plant operations can result in significant liquid volumes. Specific examples include design pump seal leakoff, new and spent processing media backwash, transfer and cleaning evolutions, and filter backwash. At the most successful stations, liquid waste generation and disposition guidelines, goals, and controls and procedures related to system draining and/or maintenance evolutions are incorporated directly into the work planning process. The most successful programs have found that proceduralized water management controls and guidelines for routine operational activities have resulted in cost effective and optimum waste liquid treatment. Advanced identification and knowledge of liquid influent volume and chemistry and activity characteristics can provide valuable information for defining optimal routing and processing strategies. That information also provides opportunities for mapping current and projected liquid inventories to ensure adequate tankage is available for uninterrupted plant operations.

2.9.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Develop work control processes and procedures that integrate management of liquid waste generation and processing.
   - Include processing impact queries in work control documents.
   - Include processing evolutions as line items on work control schedules.
2. Require radwaste/operations involvement in routine/daily evolutions and in the preplanning process to ensure generated volumes are managed and processed in the most cost effective manner.

   Items to consider as part of the planning program should include the following:
   - Radwaste notification.
   - Projected volume.
   - Source and quality of liquid.
   - Alternatives to processing.
   - Best drain point, draining equipment (i.e. flanges, hoses, fittings, etc.), drain path, and collection tank.
   - Optimum treatment method.
   - Impact on parallel processing operations.
   - Impact on effluent activity.

   > **INDUSTRY EXPERIENCE**: At one utility, the planning and operations system draining procedures include very specific, clear direction. The plans and procedures include valve number, drain point location, the volume of liquid expected, portable drain manifold requirements, physical clearances, hose size, drain destination, length of hose, and the specific drain point and drain termination connection types.

3. As part of the planning process, coordinate work evolutions with media end-of-life (i.e., internal system maintenance or spent fuel pool (SFP) work with end of filter and/or demineralizer run).

2.9.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.

2. EPRI. Waste Logic™ software programs and user manuals.

3. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

2.10 Program Element: Outage Planning and Control

2.10.1 Program Impact

Outages typically generate the largest acute volume of liquid waste that can challenge water inventory management success. Examples include system draining, refueling, system chemistry adjustments, spent media changeouts, and unit startup. Frequently, the chemical and activity characteristics of the generated liquids may require realignment of operational processing strategies and may impact the ability to meet process effluent standards.

Therefore, planning and work control are the most critical elements of successful outage liquid waste management - understanding in advance the projected waste sources and volumes can lead to successful waste segregation, processing and effluent recycling, or release. Developing outage specific goals clearly communicate processing program objectives and typically improve "buy-in" from other organizations.

<u>The most successful programs have found that proceduralized work control queries and work activity and schedule logic ties providing accurate and comprehensive task specific program guidance, are critical elements of outage planning and execution.</u> That guidance provides information that addresses when the liquid will be generated, how much will be generated, where the liquid should be routed (inventory and process control), and how it should be dispositioned. The goal is to minimize the impact on inventory, effluent quality, and unit return to power. Early (six months or more) and consistent (all outage planning sessions) involvement and aggressive interaction between key station organizations is critical for optimizing outage processing strategies. Equally important are planning considerations for major projects such as chemical system/component cleaning, chemical decontamination, and major component replacement.

Additionally, at many stations, the use of dedicated LRW processing experts (one per shift) acting as processing control coordinators has proven to be extremely successful. The individuals are stationed in the central outage work control center providing <u>continuous</u> outage schedule and work plan compliance oversight and coordination of all LRW generation, processing, and disposition activities.

Even the most successful outages remain dynamic in nature, with unexpected issues driving changes to both schedule and scope. As such, a successful outage LRW plan requires flexibility and deviations in process strategies. The most important aspect of successful outage program management is to ensure those lessons learned are accurately documented and are incorporated into future outage work plans. Frequently, the outage water control expert position also provides immediate feedback and direction for resolving emergent processing issues and can capture and evaluate lessons learned feedback.

The benefits of a detailed and integrated outage processing plan combined with specific outage processing goals and consistent, high quality oversight include:

- Minimization of liquid waste requiring processing and discharge.
- Improved coordination between system draining requirements and start of maintenance activities.
- Better ALARA coordination between system draining and work activities. In some instances, primary system draining may be scheduled after completion of work in an area to minimize the dose rates in certain areas of the plant during maintenance activities.
- Minimization of microbiological growth nutrients in liquid waste requiring processing.
- Improved inventory control minimizing the impact on treatment system capabilities and return to power.
- Liquid characterization for soluble and insoluble activity.

2.10.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Incorporate liquid processing expert involvement in all phases of outage planning as early and as consistently in the planning schedule as practical, beginning with the preliminary outage work list.

2. Develop outage specific goals for generation and/or inventory percentage, processing personnel exposure, and resultant waste generation.

3. Develop proceduralized work planning queries and controls that account for liquid waste generation, processing, and effluent disposition.

   Items to consider as part of the work control program should include the following:

   – Schedule logic ties linking generation and disposition to work and unit operation activities.
   – Radwaste liquid **pre**-generation notification incorporated into operation, refueling and maintenance procedures.
   – Projected volume.
   – Impact on outage inventory.
   – Source of liquid.
   – Chemistry and activity characteristics of the liquid.
   – Alternatives to processing.
   – Best drain point, draining equipment (i.e. flanges, hoses, fittings, etc.), drain path, and collection tank.

- Optimum disposition path (e.g., capture non radioactive liquids in drum, carboy, bladder and drain to monitored, clean release pathway)
- Optimum LRW treatment method.
- Impact on parallel processing operations.
- Impact on effluent activity.

> **INDUSTRY EXPERIENCE 1**: At one utility, the planning and operations system draining procedures include very specific, clear direction. The plans and procedures include valve number, drain point location, the volume of liquid expected, portable drain manifold requirements, physical clearances, hose size, drain destination, length of hose, and the specific drain point and drain termination connection types.

4. Create an outage position for continuous LRW processing coordinator coverage.
   - Ensure the individuals are knowledgeable in outage evolutions, liquid processing, and resultant waste disposition options.
   - The individual should be physically located in the outage work control center on a schedule commensurate with outage activity impact on liquid generation and processing.
   - Ensure the individual is empowered to make decisions related to liquid volume and process management.
   - Use that position to review, capture and collate lessons learned.
   - Ensure that position's presence and role is addressed in outage communications and documents to ensure the station staff is aware of, and utilizes that resource.
5. Involve Radwaste personnel in the early stages of major project planning. In addition to the elements discussed above, the following issues should be adequately addressed to ensure continued program success.
   - Impact of specialty solutions and chemicals on processing equipment or media.
   - Available waste treatment and VR options.
   - Final waste form and disposal considerations (i.e., chelants).
   - Impact of liquid system drain, fill, and operational activities on processing system influent chemistry. Issues to consider include aggressive chemical species, increased particulate activity resulting from system disturbance, biogas generation, and increased liquid waste volumes as a result of system draining and/or pre-use replaced component testing.
6. As part of the planning process, coordinate work evolutions with media end-of-life (i.e., internal system maintenance or spent fuel pool (SFP) work with end of filter and/or demineralizer run).

2.10.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.
2. EPRI. Waste Logic™ software programs and user manuals.
3. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

2.11 Program Element: Equipment and Materiel Condition

2.11.1 Program Impact

Radwaste equipment and materiel condition can significantly impact radwaste process options and in some instances balance of plant operations. A successful program in this area can result in a reduction in liquid and solid waste generation, and optimum effluent quality for recycle or release. In order to effectively monitor and assess the performance of processing systems, the basic process stream parameters must be known by the system operators. Inoperative equipment does not allow process operators to continuously monitor process parameters and to make adjustments to processing operations as necessary.

Assigning dedicated radwaste processing operators to the Radwaste organization typically results in improved performance, consistent process results, and the development of "system experts."

Each utility must determine the minimum operating requirements for each system based on system safety significance and criticality to the plant. E.g., Radwaste equipment has less significance than safety related equipment and therefore typically does not have to meet the same level of configuration control and redundant availability. Clearly communicated and proceduralized management expectations for operational control and human performance will ensure that operators do not misapply less stringent requirements appropriate for Radwaste equipment to higher tier equipment with higher minimum standards.

Industry experience clearly demonstrates that sludge and the liquid inputs to liquid and solids collection tanks contain chemical impurities that can attack tank welds and wall thickness, which may result in failure.

> **Industry Experience**: Several stations have experienced tank failures that were caused by inadequate tank sludge control. (USNRC Information Notice No. 79-007, Rupture of Radwaste Tanks; and 96-14, Degradation Of Radwaste Facility Equipment)

Frequently, plants delay or avoid tank inspections because of the personnel exposure associated with those efforts. Exposure should not be the controlling factor, as the level of effort and exposure associated with tank failure, recovery, and repair or replacement would most likely exceed inspection related exposure and costs. Additionally, the personnel and plant safety aspects of premature tank failure far outweigh the negative aspects of inspection related exposure.

2.11.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Establish a LRW task force with efforts focused on equipment performance, identifying deficiencies, and implementing solutions. Several stations have successfully accomplished this through the use of High Impact Teams (HIT).

2. Similarly, many stations have established a Fix It Now (FIN) Team (or similar) which also is responsible for immediate resolution of equipment deficiencies.

> **INDUSTRY EXPERIENCE**: One station has established leak and RW Control Room deficiency FIN Team Performance Indicators. The status of those indicators is reported in the daily plant management meetings.

3. If equipment repairs are not feasible, consider replacement of the equipment with technologically advanced equipment. This would give operators the necessary and improved tools to perform liquid processing in a more efficient and cost effective manner.

4. Assignment of work/repair request priority commensurate with the impact the deficiency has on processing results and costs. The radwaste program manager should be included in the process.

5. The radwaste (RW) manager should be aware of LRW deficiencies and provide the necessary motivation to achieve their resolution.

6. Inspect collection tank on a routine basis and desludge those tanks as required. Many stations require a visual inspection every 2-3 years with cleanout efforts based on the inspection results. Several companies provide proven remote tank cleaning services for the industry.

2.11.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.

2. EPRI. TR-105859, “Cost Effective Liquid Processing Programs”, 1995.

3. EPRI. NP-7386-V41995, “Radwaste Desk Reference Volume 4: Mixed Waste”.
4. EPRI. “Filter Demineralizer Performance Improvement Program”, 1996.
5. USNRC. Regulatory Guide. 1.56, "Maintenance of Water Quality in Boiling Water Reactors”, Revision 1, 1978.
6. US DOE. DOE/LLW-144, “Guidelines for Mixed Waste Minimization”, 1992.
7. USNRC IN No. 79-007 “Rupture of Radwaste Tanks”.
8. USNRC IN No. 96-14 “ Degradation Of Radwaste Facility Equipment At Millstone Nuclear Power Station, Unit 1”.

2.12 Program Element: Exposure Control

2.12.1 Program Impact

The primary reason for processing radioactive liquids is to remove radioactivity and chemical impurities. In all currently used techniques, the activity is concentrated in or on a solid media or in a liquid waste slurry. The net effect is that personnel exposure is associated with system operation, maintenance, testing, and waste packaging and storage and/or disposal. The exposure sources are varied and dependent on process type, system configuration, plant installation, remote technology use, shielding, influent characteristics, and liquid process volumes.

In addition, new technologies such as membranes further increase the concentration of activity on the membrane material. This also results in a reject stream that is recycled and further concentrated to a site specific limit, then routed for additional treatment and disposition. Industry experience has clearly demonstrated that these processes have the ability to result in relatively high dose rates on both membrane surfaces and/or the concentrated reject. This technology attribute mandates careful consideration of equipment design and location, and membrane cleaning efficiency and frequency, to minimize the personnel exposure related to routine operation and maintenance.

High-activity crud-burst media may contain more activity and the transfer of the media may require special handling.

Exposure resulting from liquid processing evolutions should be routinely evaluated to identify process or equipment changes that can result in reduced exposure to station personnel. An equally important benefit is reduced station exposure and an improved ALARA rating with industry agencies.

INDUSTRY EXPERIENCE: Processing shutdown crud burst cleanup media sluice liquid at one station produced 7 R/hr membrane reject and 300 mR/hr membranes. This created significant handling and packaging ALARA challenges.

2.12.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Routinely evaluate liquid processing exposure and sources. Consider the impact of the following:
   – Equipment reliability and activity buildup.
   – Technology currently in use versus cost for replacement.
   – Functionality of media in use and reuse of media in other applications.
   – Media changeout criteria.
   – Membrane dose rates and cleaning frequency.
   – Membrane reject concentration limits, collection, treatment, disposition, and packaging.
   – Acquired dose as a function of task for processing during normal operations or outages. It may be necessary to have separate RWP's for individual task dose.
   – Portable equipment (e.g. hoses) dose rate and replace when they are high.
   – Communication of area dose rates to workers using area radiation monitors with local readouts and alerts.
   – Evaluate procedures for clarity to prevent re-working tasks.
2. Evaluate the use of evaporators carefully. Consider the exposure associated with operations, maintenance and waste packaging. Carefully evaluate retiring the evaporator and replacing it with alternate advanced technology.
3. Filter changeout criteria should be evaluated to ensure filter use is optimized.

> **KEY CONSIDERATION:** "Clean" filter differential pressure (dP) profiles should be established and not exceeded. Precoat, non precoat and minimum precoat filter/demineralizers are particularly susceptible to irreversible fouling that can result in elevated dose rates and increased personnel exposure.

4. Verify that exposures associated with spent filter handling are minimized by using remote tooling and grippers and shielded portable transfer containers. Evaluate packaging practices to ensure package efficiency is maximized and personnel exposure is minimized.

> **INDUSTRY EXPERIENCE:** _At several stations, computer assisted design (CAD) systems have been successfully used to develop optimum loading plans for high exposure solid wastes. This tool can be effectively used to optimize loading strategies, minimizing costly void space and personnel exposure.

5. Demineralizer use and transfer techniques should include analysis of the following:
   - Vessel shielding and personnel access controls—Sky shine from demineralizer vessel.
   - Vessel internal design—Rinse and retention element type and sizing.
   - Transfer line flush capabilities.
   - Using remote valve and sample manifolds instead of interchangeable flexible hoses requiring local manipulation in the demineralizer vicinity.
6. Use automated remote resin/slurry samplers to ensure representative 10CFR61 samples are obtained with minimal personnel exposure.
7. Surrogate 10CFR61 filter sampling and analysis in accordance with the EPRI Low Level Waste Characterization Guidelines, TR-107201. If required, consider remote options including remote grippers or hole saw.
8. Monitor dose rates, routinely inspect, and clean sumps, tanks, and filter and demineralizer vessels as necessary to remove potential sources.
   - The key is to perform this evolution on a routine basis, precluding the development of significant solids in an undesirable form.
   - Radiation monitoring should be done using remote monitoring technology.
   - An additional benefit of this process is reduced solids carryover into the process stream and probable improvements in process performance and improved effluent quality
9. The use of robotics should be considered for inspection and cleaning evolutions based on plant experience, component access, and supplier technical input. The related remote operations permit hydrolasing and slurry removal with minimal personnel exposure.
10. Specify and use remote controls and programmable logic controllers to the extent practical.

> **CAUTION:** Increasing the number of remote controls (valves, operators, PLC, etc.) increases costs and can increase the potential for failure. Remote operators located behind shield or adjacent to source term and failure may require dose intensive repairs.
> Conversely, programmable controllers can minimize operator error by automating sequenced process steps.

11. Locating remote and locally operated equipment in accessible, low dose areas to facilitate calibration, corrective and preventative maintenance, and replacement.
    - Carefully evaluate the impact of installed and/or temporary shielding on equipment accessibility.
12. Locating gauges and instrumentation in accessible, low dose areas to facilitate calibration.
    - Carefully evaluate the impact of installed and/or temporary shielding on equipment accessibility.

13. Additional process or technology specific exposure control guidance is contained in the applicable sections of this report.

2.12.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.
2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.
3. EPRI. "Filter Demineralizer Performance Improvement Program", 1996.
4. EPRI. "Proceedings; Second Workshop on Condensate Polishing with Powdered Resin", 1991.
5. USNRC. Regulatory Guide. 1.56, "Maintenance of Water Quality in Boiling Water Reactors", Revision 1, 1978.
6. EPRI. TR-1009566, "Non-Metal Filter Study", November 2004.
7. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.
8. EPRI. RS-107201, "Low Level Waste Characterization Guidelines", 1997.

3 LIQUID WASTE INFLUENT VOLUME MINIMIZATION

3.1 Overview

Liquid waste processing influent volumes are often impacted and/or controlled by station organizations external to the processing program. A concerted effort by multiple plant organizations is required to successfully reduce liquid process volumes. Reducing the sources of liquid waste benefits a station in numerous ways, including the following:

- Lowers the volume of liquid waste requiring processing, increasing the options available for cost-effective treatment—Creates time to evaluate processing options.
- Enhances control over influent water quality.
- Lowers processing costs—all liquid waste processing activities, regardless of method, have a cost per gallon associated with them.
- Minimizes the environmental impact.
- Decreases the volume of solid radwaste requiring packaging and disposal.
- Reduces makeup water requirements.

Prior to implementation of the guidance in this section, the program manager should first review their plant practices, processes, and evolutions that generate LRW. The review should include expected LRW volumes and LRW drain systems.

3.2 Program Element: Influent Identification and Evaluation

3.2.1 Program Impact

Identifying inputs to the liquid processing system(s) is the first logical step in minimization of process volumes. Once the influent source and volume are identified, it can be evaluated to determine the best minimization method. Several techniques for identification incorporate data generated by installed plant equipment such as sump run timers and tank level indicators. Others employ additional investigational methods such as performance of water balances on a cyclic basis, or chemistry analysis to fingerprint the source and determine its origin based on chemical or radioactive characteristics.

3.2.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Routinely identify all major sources that contribute to the liquid waste volume generated such as:
   - Direct influent to the sumps and tanks.
   - Sump inputs to tanks.
   - Valve and equipment internal and external leakage.
   - Process waste (i.e., resin cleaning, chemistry samples, on-line monitors, etc.).
   - Implement a 'report card' for waste generators. This concept generates a summary of generated volumes, quality, and their impact on solid waste volume, cost, and/or exposure. This is presented to the "actual" waste generator department head on a periodic basis.

> **NOTE:** It is important to initially limit the scope of this program to assure focused attention is given to the priority inputs, and that the plant staff sees an improvement in this area is achievable.

2. Evaluate whether the source(s) and volume generated are necessary for plant operation, or if the source(s) are the result of equipment/component leakage. As part of the evaluation, consider the following:
   - Do the source chemistry characteristics result in additional solid process waste being generated?
   - Is the leakage at the design flow-rate? Many plants have experienced increased flow rates with equipment seal and packing "wear-in" and have not readjusted the new seals to the minimum allowable specifications.
   - Is the design leak-off consistent with modern technology (i.e., live load mechanical seals and packing), or with the least achievable leak-off for that design?
   - Is the cost for processing currently installed seal package/packing leak-off volumes over the expected life of the plant cost effective when compared to an improved seal package installation?
   - Are the conductivity, organic contamination, nutrient level and other physical characteristics affecting processing and/or can this information be used to help identify the source of the liquid.
   - Is an alternative method available that would minimize the generation of LRW (i.e., dust mop vs. wet mopping, recycle liquid from system draining back into the system vs. draining to radwaste)?

> **INDUSTRY EXPERIENCE**: At one utility, the planning and operations system draining procedures include very specific, clear direction. The plans and procedures include valve number, drain point location, the volume of liquid expected, portable drain manifold requirements, physical clearances, hose size, drain destination, hose length, and the specific drain point and drain termination connection types.

> **INDUSTRY EXPERIENCE**: The process of hydrolancing generates two waste streams. The first is the lance stream itself. The second is the bypass flow from the high pressure pump that flows at 2 - 5 gpm whenever the high pressure lance is not being used. When using high pressure hydrolancing to clean closed cooling water (CCW) heat exchanger tubes, one plant directs the organic laden waste and bypass flow directly into the service water outlet line of the CCW heat exchanger. This is accomplished using simple pumping systems and existing line taps. The advantage of redirecting this waste stream is reduced loading on the radwaste processing system.

3. Use installed equipment such as sump run timers, control room data loggers, or flow totalizers to determine the time and approximate volume of liquid pumped out of specific sumps. These data can aid in identification of planned plant evolutions or anomalies occurring during that time period. Once identified, the specific liquid waste generation evolution can be evaluated to determine the feasibility of influent minimization or elimination.

4. Use tank level indicators to perform a daily water balance for the waste system. Similar to sump run timers, the data can then be used to evaluate inputs for minimization or elimination.

5. A chemistry analysis of sump contents on a routine basis can provide useful data. The knowledge of sump conductivity, pH and radioactivity can be useful for tracing the origin of processing system inputs and evaluating processing options. These data can be used to quickly identify "off normal" waste influents.

6. Historical data (or data from similar units at dual unit sites) related to volumes can be effective for identifying improvement opportunities.

7. Use a unit specific "drain tree" to assist in identification of unknown input identification.

> **INDUSTRY EXPERIENCE**: At least one station routinely uses installed drain line clean-out trap access plugs to visually observe, sample, and quantify inputs of unknown origin.

3.2.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.

2. EPRI. “Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations”, 1993.

3.3 Program Element: Segregation

3.3.1 Program Impact

Segregation of liquid wastes prior to processing can be one of the most effective methods of reducing process volumes with minimal effort or cost. Creative analysis and use of installed plant piping, sumps and tanks can often result in the ability to effectively separate waste streams based on chemical and activity characteristics and process option. This facilitates the use of batch specific process or release strategies.

> **INDUSTRY EXPERIENCE**: At least one station employing membrane technology has effectively segregated influent wastes based on characteristics to minimize the impact on RO membranes. The process configuration is altered to bypass membranes when not required to meet effluent goals, or when the influent characteristics such as TOC would negatively impact the membranes efficiency or useful life.

Low activity wastes can sometimes be released without expensive treatment processes, requiring only minimal filtration and/or monitoring prior to release to ensure compliance with release criteria. Similarly, these wastes are also frequently low quality wastes that result in less than desirable process performance, can prematurely deplete processing media, and result in increased solid waste volumes.

Additionally, in many instances, processing some waste streams using alternate methods may be more cost effective.

> **INDUSTRY EXPERIENCE**: Several stations use partially depleted media (in existing plant demins or HICS) or simple filtration for low quality waste processing. Typical all-inclusive costs associated with those processes are <$0.25 per gallon. A significant savings can be realized when a high technology processing system such as filter and demineralizer or membrane system costing $0.60 per gallon is not challenged by this waste stream. Using this scenario, alternate processing for 400,000 gallons annually would result in an annual cost savings of ~$140,000.

Another option frequently overlooked is recycling back to the system from which the liquid waste originated. This method of liquid disposition requires preplanning and may require special or dedicated drain and collection equipment.

> **INDUSTRY EXPERIENCE:** Several stations completely drain and rinse waste holding tanks prior to outages. That volume is used to collect reactor coolant system (RCS) draindown waste augmenting normal RCS holding tank capacity. After sample and purity confirmation, the "waste" liquid is recycled to the primary system.

3.3.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Evaluate all low activity and clean inputs to liquid process systems for alternate disposition options. As part of the evaluation consider the following:

> **CAUTION:** The station should carefully review UFSAR, Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

   – "Retired" components available for use such as pipe, pumps and tanks.

   – Use of laundry and decontamination solution waste tanks for filtration and monitored release.

> **CAUTION:** The station should evaluate the impact of aerated water on the system to which the water is being recycled (e.g., closed cooling hydrazine corrosion control additive concentration). A 10CFR50.59 and industrial safety evaluation may be warranted.

   – Drainage of systems to portable collection containers and recycle the liquid back into the system. Figure 3-1 contains a simplified diagram of one configuration for this process.

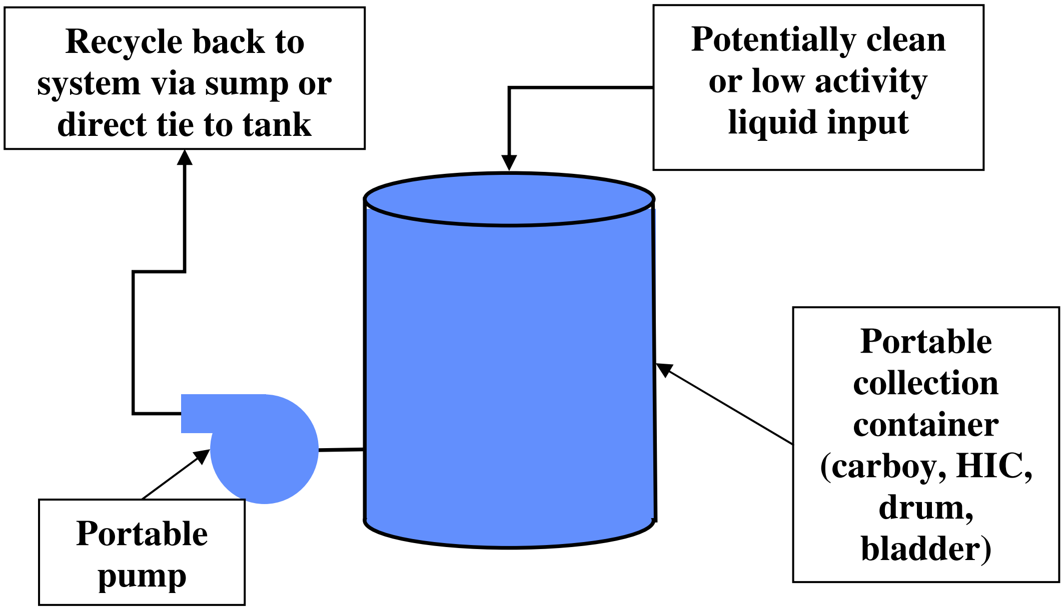

Figure 3-1
Typical Recycle Configuration.

2. Establish a controlled tie in at the effluent of radwaste processing system equipment prior to release monitor tanks to permit input of liquid wastes acceptable for direct monitored release, which precludes unnecessary processing.

> **INDUSTRY EXPERIENCE**: At least one station has installed a clean waste header to divert "clean" wastes directly to tanks for release following monitoring. The header is non-safety related, is PVC and requires minimal installation engineering and labor effort. The header access ports are locked and controlled by a select group of station personnel.

3.3.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

3. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

4. US DOE. DOE/LLW-144, "Guidelines for Mixed Waste Minimization", 1992.

5. The EPRI document titled “Radwaste Desk Reference Volume 4: Mixed Waste”.

3.4 Program Element: Leak Repair and Prioritization

3.4.1 Program Impact

Leakage from plant equipment negatively impacts the processing program in several ways. Typically, leakage increases the liquid volume requiring processing, as well as adding nutrients and oils that cause biogassing. The leak rate is often not quantified on a routine basis, and therefore plans cannot be developed to optimize process performance. A secondary issue is the effect on contamination controls and personnel exposure. Leaks can result in increased area contamination, increased solid waste generation and potentially increased personnel exposure as a result of more stringent contaminated area entry requirements. Active leaks negatively affect the plant’s materiel condition as well as the plant staff perception of the effectiveness of the equipment maintenance program.

Leaks can also result in decreased processing performance through the introduction of undesirable chemical species to the processing system. Refer to Section 5 of this document for further discussion on the effects of influent quality on process performance.

3.4.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Develop and maintain an accurate list of existing plant leaks, including both clean and contaminated system leaks. The following techniques may enhance efforts to accurately identify leakage sources:
   - Visual observation - boroscope, remote video.
   - Portable temperature indicating/thermography devices.
   - Chemistry analysis of liquids.
   - Microbiological analysis of liquids.
   - Stethoscope/listening devices.
   - Use installed clean-out trap access plugs to visually identify, quantify and sample inputs of unknown origin.
   - Radiation detection devices
2. Include a list of top priority leaks on the morning report or for discussion at operations-oriented management meetings.
3. Revise the station procedure for leak prioritization so that a high priority is always given to leaks that generate LRW. Particular attention should be given to high activity and high conductivity wastes that more rapidly deplete processing media.

4. Establish a multi-phase leakage reduction goal, initially targeting those that have the most significant impact on processing operations, working towards a station goal of zero leakage to process systems. In an attempt to reduce outage duration, many utilities have recently increased the amount of on-line maintenance. This has created a need to develop challenging concepts for safe and efficient leak repair to assist in achieving this goal.

3.4.3 Cross Reference(s):

None

3.5 Program Element: Planning, Work Control, and Outage Success

3.5.1 Program Impact

Planning and work control are the most critical elements of successful outage liquid waste management - understanding in advance the projected waste sources and volumes can lead to successful waste management. The most common measurements for determining the success of an outage are the number of outage days, number of tasks completed, outage cost, and personnel exposure. However, the volume of outage liquid processed, the resultant process effluent quality, and the resultant solid waste volume are effective parameters for assessing outage radwaste controls. Developing outage specific goals for these parameters clearly communicates processing program objectives and typically improves “buy-in” from other organizations. To achieve success in these areas it is paramount that many of the concepts in this document be considered and implemented well in advance of planned outages.

Outages typically generate the largest acute volume of liquid waste that can challenge water inventory management success. Sources include:

- Pre shutdown RCS dilution (for PWR plants)
- System draining
- Refueling
- System chemistry adjustments
- Spent media changeouts
- Unit startup

<u>The most successful programs have found that proceduralized work control queries and work activity and schedule logic ties providing accurate and comprehensive task specific program guidance, are critical elements of outage planning and execution.</u> That guidance provides information that addresses when the liquid will be generated, how much will be generated, where the liquid should be routed (inventory and process control), and how it should be dispositioned. The goal is to minimize the impact on inventory, effluent quality, and unit return to power. Early (six months or more) and consistent (all outage planning sessions) involvement and aggressive interaction between key station organizations is critical for optimizing outage processing

strategies. Equally important are planning considerations for major projects such as chemical system/component cleaning, chemical decontamination, and major component replacement.

Even the most successful outages remain dynamic in nature, with unexpected issues driving changes to both schedule and scope. As such, a successful outage LRW plan requires flexibility and deviations in process strategies. Additionally, at many stations, the use of dedicated LRW processing experts (one per shift) acting as processing control coordinators has proven to be extremely successful. The individuals are stationed in the central outage work control center. There they provide continuous outage schedule and work plan compliance oversight, coordination of planned LRW generation, processing, and disposition activities, and evaluation and management of emergent challenges.

Another critical aspect of successful outage management is to ensure that lessons learned are accurately documented and incorporated into future outage work plans. Frequently, the outage water control expert position also provides immediate feedback and direction for resolving emergent processing issues and can capture and evaluate lessons learned feedback.

The combined benefits associated with a detailed and integrated outage processing plan, specific outage processing goals, and consistent, high quality oversight include:

- Minimization of liquid waste requiring processing and discharge.
- Improved coordination between system draining requirements and start of maintenance activities.
- Better ALARA coordination between system draining and work activities. In some instances, primary system draining may be scheduled after completion of work in an area to minimize the dose rates in certain areas of the plant during maintenance activities.
- Minimization of microbiological growth nutrients in liquid waste requiring processing.
- Improved inventory control minimizing the impact on treatment system capabilities and return to power.
- Liquid characterization for soluble and insoluble activity.

Meeting the established goals creates a win-win situation for all parties involved.

3.5.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Aggressively pursue involvement in all phases of outage planning as early in the planning schedule as practical, beginning with the preliminary outage work list.

INDUSTRY EXPERIENCE: Several plants integrate system draining and water movement needs into their refuel outage work schedule. One plant maintains a water plan for both primary and secondary systems. As a result, that station has been able to reduce floor drain influents by 60% by developing an integrated water plan during outages. During a recent outage, floor drain influent quantities were not significantly different than quantities seen during normal operations.

INDUSTRY EXPERIENCE: At one utility, the planning and operations system draining procedures include very specific, clear direction. The plans and procedures include valve number, drain point location, the volume of liquid expected, portable drain manifold requirements, physical clearances, hose size, where to drain, length of hose, and the specific drain point and drain termination connection types.

Examples of water plan entries are shown below.

Table 3-1
Example Primary Water Movement Plan

DATE & Ref. #	MODE	ACTIVITY	ACTION	COMMENTS
10/12* DNM30005	3	Borate RCS to >1800 ppm	Approx. 21,000 gal of 7000 ppm from BAST 'B' required. Divert RCS ~21,000 gal to RHUT 'B'	BAST "A" and RWST are operable boron sources.
10/12* DNM30030	3	CVCS/BTRS Flushes & Degas	Drain to RHUT 'B'	<5000 gal OTN-BG-00004
10/12*	5	Maintain BAST 'A' and the RWST operable.	**During 'A' train electrical outage, align 'B' boric acid transfer pump to 'A' BAST to maintain 'A' BAST operable.**	Volume in 'A' ~80% This is to maintain both the RWST and 'A' BAST operable. BAST "B" will be diluted to 2200 - 2400 ppm B for RFP cleanup system and refilling of the RWST.
10/12*	5	Adjust 'B' BAST to 2200 - 2400 ppm demin water.		This is in preparation for operation of the RFP cleanup system and RWST fill. Tank is approximately 2400 ppm.
	5	Crew briefing prior to drain/refill	Fill 'B' BAST to ~60% level with demin water. Recirc tank and sample. **TANK IS ISOLATED DUE TO 'A' TRAIN ELECTRICAL OUTAGE**.	SOS 95-0872
10/14* DNM50052	5	Drain RCS to a Pressurizer level of 20 - 25%	Send 10,600 gal to RHUT 'B'	RHUT 'B' is to be used for drain down of the RCS.
10/14* DNM50054	6	Drain RCS to 6" - 12" below flange	Drain 6,400 gal to RHUT 'B'	Drain Rx vessel to RHUT 'B' via letdown. Both fuel pool cleanup filters in service per updated final safety report (UFSAR) during refuel ops. OTN-BB-00002, RTN-HC-00500
10/14-10/15	5	Batch to 'A' BAST	Batch 5 batches to 'A' BAST to raise level to ~55%	'A' BAST remains operable, sample each batch tank to verify contents.
10/15 PWM001A	6	Adjust RHUT 'B' to 2200 - 2400 ppm B	Chemistry to sample Need ~50,000 gal of 2200 - 2400 ppm B for flood-up.	Required to support flood-up to 23' above flange. Level at 65% (34,000 gal) at 2257 ppm B. **Tag RHUT 'B' as 2400 ppm boron**

2. Establish outage specific goals related to liquid volume generated, resultant solid waste generation, processing personnel exposure, and inventory as a percentage.

3. Work with system engineers, chemistry, operations and planners to determine the following information:

    – Projected volumes from each task or evolution.
    – Best drain path to segregate and optimize system performance.
    – Ability to capture and recycle liquid versus process and release.
    – Ability to monitor and release without major processing.

- Alternate system isolation and draining or maintenance options that would result in decreased liquid waste volumes.
- Optimum outage task sequence to maximize use of filters, resins and other processing media.

CAUTION: Outages are dynamic in nature - established water management plans should be reviewed frequently (dependent on outage duration and scheduled work) and revised as necessary.

NOTE: Successful program managers constantly challenge established outage liquid waste management techniques in an effort to minimize outage liquid wastes, while simultaneously improving the quality of LRW generated. In order to improve, "the way we've always done it" should be challenged at every opportunity with the objective to create innovative outage liquid waste management concepts.

4. Perform pre-outage equipment preparations. This includes changing process media to accommodate local work or to support planned liquid waste processing. Additionally, holdup/retention tank liquid volumes should be minimized in anticipation of outage waste generation.

5. Capture and document innovative ideas and lessons learned from each outage as well as from other stations that have successfully planned and executed outages. Similarly, input from stations that have reduced outage duration should be incorporated into the liquid waste management program.

6. Outage activity communication via
   - Outage readiness review
   - Newsletter
   - Outage handbook

7. Consider developing an outage readiness checklist using the following guidance as a template.

Consideration		Yes	No	N/A	Comments
1.	Are planned evolutions scheduled to coincide with process media end of life/or replacement? E.g., Is a task that could create a large perturbation in the spent fuel pool water quality scheduled before the SFP demineralizer or filter is reaching its EOL or scheduled for changeout. The goal is to capture impurities on the old media prior to changeout, rather than prematurely depleting the freshly loaded new media.				

	Consideration	Yes	No	N/A	Comments
2.	Is LRW management staff involved in the earliest stages of outage planning?				
3.	Are all water volume movements of >100 gallons included in formal plans, schedules and procedures?				
4.	Are their plans for primary and secondary waste streams?				
5.	Are the proper tools/equipment for water movement on-site and available for use at the appropriate locations (e.g., hoses, pumps, fittings, funnels, bladders, etc.)?				
6.	Are vendor contracts/specifications/procedures reviewed to ensure chemicals that adversely impact LRW processing are properly controlled or banned from use?				
7.	Are water movements coordinated with normal/routine processing to preclude generation of liquid volumes greater than tank capacity or to negatively impact process effluent quality?				
8.	Are holdup/retention tank liquid volumes minimized in anticipation of outage waste generation?				
9.	Has the station defined outage specific goals related to liquid volume generated, solid waste generated and liquid effluent activity?				
10.	Work with system engineers, chemistry, operations and planners to determine the following information:				
	• Projected volumes from each task or evolution.				
	• Best drain path to segregate and optimize system performance.				
	• Ability to capture and recycle liquid versus process and release.				
	• Ability to monitor and release, without major processing.				
	• Alternate system isolation and draining or maintenance options that would result in decreased liquid waste volumes.				
	• Optimum outage task sequence to maximize use of filters, resins and other processing media.				
11.	Are established water management plans reviewed frequently (dependent on outage duration and scheduled work) and revised as necessary due to the dynamic nature of outages?				
12.	Are innovative ideas and lessons learned from each outage as well as from other stations that have successfully planned and executed outages captured and documented? Similarly, input from stations that have reduced outage duration should be incorporated into the liquid waste management program.				

3.5.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

3.6 Program Element: Precipitation and Ground Water

3.6.1 Program Impact

As a result of the number, size and complexity of nuclear plant structures, many stations experience the intrusion of rain and ground water to LRW collection sumps and tanks. Additionally, several stations have installed moats or berms around tanks external to the plant. The tanks contain potentially contaminated liquids and therefore, the precipitation collected in these moats is often routed to the radwaste processing system.

The collected rain, ground and moat liquid is typically free from site specific contamination, but does contain microbes. If contained prior to commingling with other plant LRW it can ordinarily be released without processing. However, frequently the plant's structural complexity results in difficulty with routing the water to implement this approach.

Therefore, the waste is often routed to radioactive sumps and waste tanks, requiring processing prior to release. In addition to increasing program costs associated with increased process volumes, these waste streams typically contain impurities (such as particulate organic matter), or can "flush" impurities from floor and equipment surfaces into the process system, negatively impacting process performance. A detailed discussion related to water quality impact is contained in Section 5 of this document.

3.6.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Minimize the volume of precipitation and ground water that requires processing by identifying and eliminating points of intrusion through the use of sealants.

2. Install temporary or permanent containments to collect the groundwater around those sources that cannot be cost effectively repaired. The water should be sampled and monitored during release without processing. This can be accomplished as a stand alone evolution, or routed to the effluent of the processing system prior to release monitor tanks. Alternatively, the volume can be pumped to installed low quality liquid collection tanks such as laundry or decontamination waste tanks that are only filtered and monitored for release, which bypasses other liquid processing components.

3.6.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

3.7 Program Element: LRW Resulting From Process Media Handling

3.7.1 Program Impact

> **NOTE:** Plant experience has consistently demonstrated that this waste stream is one of the most difficult to process.

Transferring and/or packaging new and spent processing media such as ion exchange material or carbon can generate large volumes of liquid waste that requires processing. Spent media vessel sluice or carbon vessel backwash volumes typically range from as low as 1,000 gallons to as high as 30,000 gallons per evolution. Often the empty media vessel requires additional rinsing to remove residual crud (the bathtub ring) minimizing the potential for immediate contamination of the new media charge. New media are then sluiced into the vessel and possibly rinsed prior to being placed in service, which generates additional liquid waste.

Transferring waste media from storage tanks to the shipping package can result in significant volumes of package decant wastes. Additionally, these wastes typically have high activity and solids content associated with them. This negatively impacts processing operations.

At some stations ultrasonic resin cleaning (URC) systems are used for condensate deep bed resin cleaning. URCs typically generate large volumes of waste water that require processing prior to recycle to a condensate storage tank (CST).

> **INDUSTRY EXPERIENCE**: A single URC typically generates between 15,000 and 30,000 gallons of waste liquid, with some stations generating > 45,000 gallons per URC. Using an average of 30,000 gallons per URC with one demineralizer cleaned per week, results in an annual waste system influent volume of ~1,560,000 gallons. At one station, the contracted LRW processing service is $0.15 per gallon. Processing their waste liquid produced during URC results in an annual processing cost of in excess of $234,000.

3.7.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Perform an analysis of media transfer operations to identify the optimum volume for media sluice, backwash, and rinse evolutions. The operations, radwaste and radiation protection personnel performing the task may be a valuable source of information when determining the reason for fluctuations in waste volumes for similar evolutions.

2. Differential tank or sump volumes and/or the use of installed or portable flow instrumentation can provide valuable data for this analysis.

3. Establish a dedicated crew to perform media transfers. The crew should be provided with detailed training, chemistry support, and management support to optimize the process and minimize liquid waste generation.

4. Using the data obtained in recommendation 1, install procedural controls to provide concise guidance to operators and radiation protection personnel involved in media handling evolutions.

5. Using the data obtained in recommendation 1 and the procedural controls in recommendation 2, install improved components and/or physical controls to minimize liquid inputs where appropriate. Examples include:
   - Installation of improved vessel sparging or rinse systems.
   - Flow rate meters and/or flow totalizers.
   - Installation of manual valve stops and pressure regulators to limit flow.
   - Elimination of crud traps that result in additional ALARA flushing.

6. Evaluate the volumes of liquid generated during URC by performing a detailed review of the operational aspects of the process.

7. Evaluate and implement the use of a more efficient process for cleaning secondary resins. An advanced resin cleaning system currently being used at two stations uses a vibrating screen system and a high pressure spray to clean the resin. The system typically generates 7,000 to 8,000 gallons per operation, generating significantly less liquid waste than currently available alternatives.

8. Collection of sluice water in separate tank or container for alternate processing.

9. Filtration of sluice water prior to entry into collection tank. Consider portable filters with down flow, inside to out flow cartridges or bags. They are designed for removing large quantities of fines in such waste liquids.

10. Contact other stations concerning their experience and incorporate lessons learned.

3.7.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

3. EPRI. Waste Logic™ software programs and user manuals.

4. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

5. EPRI. TR-106928, "Liquid Waste Processing at Comanche Peak", 1996.

6. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

3.8 Program Element: Process Alternatives

3.8.1 Program Impact

Identifying and implementing alternatives to processing liquid wastes is an often overlooked option to reducing generated waste volumes. In addition to decreasing waste, this option can also result in improved influent quality and improved process performance.

At almost all sites, a few other radioactively "clean" waste streams are routed to the liquid processing system as a result of original plant piping configurations, or in some cases, as a result of historical use of these process paths. The volume of liquid introduced under these circumstances is not always significant, and in many cases the actual influent volume is often not quantified. However, the combined effect of several "minor" inputs can be significant, increasing program costs and/or negatively impacting process performance.

Feasible alternatives to liquid waste processing should always be evaluated for implementation.

3.8.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

<u>CAUTION</u> 1: The station should carefully review updated final safety reports (UFSAR), Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance. Additionally, an industrial safety evaluation may be warranted.

<u>CAUTION</u> 2: For existing system modification or alternate use, a cleanliness flush should be performed prior to use in order to minimize cross contamination of primary systems or components.

1. Identify alternatives to processing such as sample, monitor and release, while maintaining compliance with discharge permits relative to chemistry specifications, radioactivity and off-site dose criteria. ***Retired or infrequently used components and systems often provide viable alternatives with minimal capital expenditure.*** Examples of specific components to evaluate include decontamination solution tanks, laundry drain tanks and evaporator effluent retention tanks.

2. Install permanent or temporary berms to retain and segregate clean liquids for collection and monitored release.

3. Evaluate the use of semi-portable tank or bladder and pumping skids for collection and routing of clean liquid wastes. The liquid can be pumped directly to release monitor tanks or to other plant components precluding the need for normal processing.

4. Install permanent fittings at drain and vent points to facilitate temporary connections to alternate disposition paths.

3.8.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.

3.9 Program Element: Sampling Waste

3.9.1 Program Impact

At many stations, waste from sample panels and in-line monitors are routed to LRW processing systems. Isolating liquid sample streams between samples can result in inaccurate sample analysis because inadequate purge, and/or sample line residuals being introduced into the collected sample. Some sample streams require continuous flow to supply in-line chemistry monitoring instrumentation.

Continuous flow and discharge chemistry laboratory demineralized water units can generate significant quantities of liquid waste requiring processing. The liquid, while chemically and radioactively clean, can still result in increased program costs as a result of process labor and/or cost-per-gallon process contracts.

The combined sample input rate from all sources can ***easily exceed*** 3 gpm, or 1,500,000 gallons annually. This volume is often significantly higher in BWR stations.

3.9.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Evaluate alternative routing for all sample waste. Options include re-routing to condenser hotwells, radioactively clean sumps, and tanks for filtration and release. Laboratory volumes can often be emptied to carboys for alternate processing and release. It is important to ensure proposed changes are in compliance with regulatory guidance, station operating procedures and Licensing documents.

2. Modify, or placing mechanical stops for throttling the flow from all sample taps to the minimum allowable, while maintaining the proper flow for accurate chemical analysis. Consider installation of “spring” valves for demineralized water taps.

3. Evaluate the processing system input from primary sample systems. Ensure the flows are established at the minimum required for accurate sample analysis.

4. Install recycling or closed loop units for chemistry laboratory demineralized water needs.

3.9.3 Cross Reference(s):

None

3.10 Program Element: Miscellaneous Secondary System Waste

3.10.1 Program Impact

Secondary liquid waste inputs originate during system/component draining and venting, or from leakage. The most common sources of secondary waste are Closed Cooling, Service Water, HVAC, Fire Protection and Chill Water systems. Frequently, the volumes generated are significant, and are generated on a routine basis during system performance verification or PMs. Additionally, these waste streams are typically low quality, negatively impacting processing operations. They can contain significant levels of nutrients that support microbial biogassing.

CAUTION: Several of the following considerations involve reconfiguring systems, or alternate uses of existing systems. The station should carefully review UFSARs, Licensing documents and release permits prior to implementing this guidance to ensure regulatory compliance. A 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance. Additionally, an industrial safety evaluation may be warranted.

3.10.2 Guidance - Closed Cooling

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Establish water management plans based on required maintenance or performance testing to optimize treatment and/or disposition practices.

2. Perform an analysis using corrosion inhibitor addition logs and makeup water addition rates, to identify system leakage. Warehouse issuance of corrosion inhibitor may be misleading as that typically includes all stock issued, but not necessarily added to the system to date.

3. Collect and recycle as much of the generated volume as practical. The cooling water should be sampled and its reuse approved by the chemistry organization.

3.10.3 Guidance - Service Water

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Establish drain paths for releasing the waste water without processing. The liquid should be sampled and/or monitored during release to ensure compliance with plant requirements.

> **INDUSTRY EXPERIENCE**: At least one station makes use of the negative pressure created by service water pumps to vacuum drag water from the header isolated for work, to the header currently in service. This allows rapid water movement and no secondary waste is created.

3.10.4 Guidance - HVAC Condensation

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Contain all HVAC condensation and route/pump it to clean monitored systems or release monitor tanks, which bypasses normal LRW processing.

> **INDUSTRY EXPERIENCE**: As a result of humid conditions, several stations have experienced very high generation volumes from this source. They installed steel drip trays and hard piping to route all condensation to a clean waste header eliminating a significant cost per gallon processed.

> **CAUTION:** Several stations have detected tritium in HVAC condensation. These tritium sources include security building explosive detectors employ Tritiated sources that off-gas to the atmosphere, and known tritium releases from the plant ventilation system that is "recycled" by HVAC supply intake headers on adjacent buildings. All HVAC condensation should be evaluated for radioactive content prior to release to the environment.

3.10.5 Guidance - Fire Protection

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Evaluate periodic system flush requirements compared to the benefit derived. Consider reducing the flush time to an acceptable minimum, thereby reducing LRW generation.

2. Use component specific fittings and hoses to route flush water to clean monitored system headers or release monitor tanks, bypassing normal LRW processing.

3.10.6 Guidance - Chill Water

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Similar to closed cooling system waste, establish water management plans based on required maintenance or performance testing to optimize treatment and/or disposition practices.

2. Collect and recycle as much of the generated volume as practical. The cooling water should be sampled and its reuse approved by the chemistry organization.

3.10.7 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. TR-105859, “Cost Effective Liquid Processing Programs”, 1995.

2. EPRI. “Preventing Biogassing in Low Level Waste”, TR-111019, 1998.

4
IMPROVING INFLUENT WASTE STREAM QUALITY

4.1 Overview

Improving the quality of liquids to be processed can significantly reduce the volume of waste solids and process media wastes requiring disposal. This can also result in a higher quality processing system effluent for release or recycle. Additionally, influent quality improvements can enhance the performance and extend run times of processing system media and/or components.

The combined potential effects of influent waste stream impurities are:

- Unnecessary sludge generation.
- Additional processing media use.
- Generation of biogas in wet solid waste containers.
- Additional liquid handling and processing.
- Reduction in the quality of processing system effluent.

Prior to implementation of the guidance in this section, the program manager should first review plant practices, processes, and evolutions that generate LRW. The review should include expected LRW quality and LRW drain systems.

4.2 Program Element: Chemical Control

4.2.1 Program Impact

At most stations, the chemical control programs are designed to prevent contamination of primary surfaces with detrimental chemicals. Additionally, the majority of stations have expanded their program to incorporate controls to minimize or eliminate the generation of mixed wastes. ***The most successful programs also evaluate the impact chemical use and disposition has on liquid processing programs.*** Some stations have further expanded their chemical control programs to minimize the inputs of materials that stimulate biogassing of solid radwaste.

4.2.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Ensure the station chemical control procedure includes a required evaluation and controls for chemicals relative to their impact on processing system operation (and potential mixed waste generation). Chemical permits should include a clearly defined liquid waste system impact evaluation as a component of the approval process.

2. Ensure approved chemicals remain the "best" available to successfully complete the assigned task without chelating agents.

3. Evaluate the process requiring chemical use versus the derived benefit. Frequently, housekeeping processes can be performed without chemicals (i.e., routine damp mopping with water can be substituted for less frequent aggressive cleaning with detergents).

> **INDUSTRY EXPERIENCE**: At one station, floor wax (and therefore wax strippers) was used to minimize contamination buildup and improve station appearance. Floor wax, acrylic floor sealers and strippers will prematurely deplete or foul LRW processing resins and blind filter media. The potential personnel exposure saved through contamination reduction, as well as the aesthetic benefit of glossy floors, did not off-set the potential personnel exposure attributed to sluicing and packaging spent LRW processing media. The process was discontinued.

4. Eliminate undesirable chemical/solvents in the radiologically controlled area (RCA) through product or process substitution. Product users (i.e., maintenance, chemistry, operations, RP, Custodial, Decontamination Technicians) should be included in product substitution efforts. This will increase "buy-in" and help to ensure a satisfactory product is obtained, by giving them the proper tools to perform required tasks. Products currently used that would negatively impact processing operations should be prohibited from the RCA.

5. Purge the warehouse stock of all inventory of chemicals not permitted for use in the revised chemical control program. Such chemicals should include those that contain chemical species that are capable of promoting microbial biogassing. This should include chemicals used primarily in the non-RCA as well. A comprehensive stock purge will assist in ensuring undesirable chemicals aren't used in the RCA, and will reduce associated warehouse inventory taxes.

INDUSTRY EXPERIENCE: One station has successfully controlled chemicals through the use of a Chemical Use Review Board (CURB). This small, inter-discipline committee meets briefly (<20 minutes) each week to review presentations on new chemical's proposed for use. The committee then establishes adequate controls for approved chemicals in accordance with established procedures. The effort expended is minimal but has a significant impact on the success of their program.

6. Provide alternative materials that are compatible with processing media in both full strength and diluted forms. Contact industry suppliers for recommendations regarding products that have minimal-to-no impact on media.

7. Provide clearly identified containers and direction for collection of residual chemical wastes in designated locations. It is equally important to minimize frequent relocation of the containers, which minimizes worker confusion. Label all containers being used even on a temporary basis.

8. Revise training programs to incorporate specific training related to chemical controls.

4.2.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. The U.S. DOE document titled "Guidelines for Mixed Waste Minimization".

3. EPRI. NP-7386-V41995, "Radwaste Desk Reference Volume 4: Mixed Waste".

4. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

4.3 Program Element: System Draining and Drain Control

4.3.1 Program Impact

The majority of stations have elements of a formalized water management program. Liquid waste generation and disposition guidelines, controls, and procedures related to system draining and/or equipment repairs are included in successful work planning processes.

Proceduralized/integrated water management controls and guidelines can result in improved influent quality and optimum treatment.

Floor drains are potentially the source of numerous undesirable inputs to the radwaste system. At many utilities controlled area drains are not labeled to control inputs—the station instead relies primarily on training and worker awareness to control floor drain inputs. Contracted and new employees are inundated with a great deal of information during access training. As a result of this, the probability of floor drain use restrictions being retained by workers, and subsequently program success, is diminished. Labels can clearly communicate restrictions related to use of individual drains.

> **INDUSTRY EXPERIENCE**: At least two utilities have experienced complete demineralizer system break-through caused by single incidences of small quantities of unauthorized chemical intrusion via the floor drains. The resultant media replacement and disposal costs were in excess of $75,000 per incident.

Additionally, much of the solid radioactive sludge generated is directly attributable to floor drain inputs. As a result of normal foot traffic, maintenance evolutions, and plant operations, a great deal of unwanted debris such as dirt, paint chips, and other granular materials is introduced to sumps, hold-up tanks, and processing systems. This waste, once exposed to liquid and higher activity materials, is both difficult and expensive to remove, package, and dispose. Floor drain sludges have been found to be a significant source of the biogassing microorganisms that can produce problems in solid wet waste containers.

4.3.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Develop work planning controls and procedures that account for liquid waste generation and water management. Include radwaste/operations involvement in the preplanning process to ensure generated volumes are managed and processed in the most cost effective manner. Items to consider as part of the planning program should include the following:
   - Radwaste involvement.
   - Accurate identification of the liquid volume.
   - Source and quality of liquid.
   - Analysis of alternatives to processing.
   - Selection of best drain point, draining equipment (i.e. flanges, hoses, fittings, etc.), drain path, clearly identified drains and collection tank.
   - Suggestion of an optimum treatment method.
   - Liquid impact on processing operations.
   - Impact on effluent activity.
2. Ensure the above issues are addressed at the implementation level. In order for the accountable worker to effectively comply with recommendations and requirements, the proper “tools” must be made readily available to them.

INDUSTRY EXPERIENCE: At one utility, the operations system draining procedures include very specific, clear direction. The procedures include valve number, drain point location, the volume of liquid expected, portable drain manifold requirements, physical clearances, hose size, acceptable drain(s), length of hose, and the specific drain point and drain termination connection types.

CAUTION: The station should carefully review UFSAR and Licensing documents prior to installing drain socks to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

3. Install nylon drain socks in RCA floor drains based on area characteristics and an Engineering evaluation of potential impact of clogged drains on equipment in the area. The drain sock's installation, cleaning, and/or replacement should be included in housekeeping routines. Floor drains are generally designed to prevent fire protection runoff to prevent flooding of equipment. An alternate approach requires the use of a filtration or settling basin for maintenance drainage and flushing (e.g. Heat Exchangers, etc) prior to sending water to a drain.

NOTE 1: Drain socks, when properly installed and maintained, may prevent unidentified waste "plugs" in "out of sight" low flow areas. Drain socks trap unwanted debris in a dry form in a manageable location.

NOTE 2: The majority of stations using socks removes drain covers with pliers or channel lock tools, and either dry vacuum or replace the socks. Radiological impacts related to the majority of drains are minimal as they are located in radiologically clean areas. Those located in contaminated areas present no new challenges; the contamination controls already in place are normally suitable for cleaning/replacement.

4. Label all floor drains with adhesive labels. The labels should clearly communicate the intended use of each drain and any prohibited wastes. The most successful plants use labels that number the drain and prohibit ***all*** liquid wastes from disposal in floor drains without specific concurrence from the radwaste or chemistry manager/supervisor. Adequate pre-job planning would preclude the need for non-emergency and unplanned drainage into floor drains.

5. Install mushroom caps on raised standpipe drains. Installation of mushroom caps precludes the need for temporary covers, prevents installation of hoses into the drains, and allows accumulated liquids on floor surfaces to drain as intended.

> **CAUTION:** The station should carefully review UFSAR, Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

6. Plug drains in high risk areas to prevent inputs of inappropriate liquids or other materials. Examples include designated storage areas for chemicals, lubricants and painting supplies.

> **INDUSTRY EXPERIENCE**: One plant's component hold-off procedure requires installation of temporary floor drain plugs in the work room in all drains adjacent to the component to be drained. The Maintenance task supervisor is responsible for containing and cleaning up residual liquid. After draining and draining cleanup are complete, the plugs are removed and work progresses.

4.3.3 Cross Reference(s):

None

4.4 Program Element: Influent Characterization – Sample Collection and Analyses Type and Quantity

4.4.1 Program Impact

A key element of a successful liquid waste processing program is adequate chemistry characterization of inputs to processing systems. Sample analyses are a critical diagnostic tool for optimizing program performance. Understanding the challenge posed by influent liquids allows for deployment of appropriate process technologies, configurations (batch specific lineups), and media. As such, it is important to carefully evaluate the sample analyses being performed and their frequency. Additionally, the information is useful in evaluating proposed processing enhancements.

Many stations have implemented liquid waste influent characterization plans, with the scope of those plans defined by station staff and analytical equipment availability. However, the vast majority of programs are of very limited scope and the issue is further exacerbated by not fully utilizing the available data.

It is equally important to clearly identify what sample parameters will provide data that can be used for program performance or improvement analysis. The quality and use of the data is more important than the quantity. Balancing the workload and derived benefit will prevent over-analysis of influent waste streams minimizing the impact on labor and laboratory resources. Conversely, the lack of data analysis can, and does, result in less than desirable performance, generating unnecessary solid waste and negatively impacting processing program results and cost.

KEY CONSIDERATION: **Identifying and routinely characterizing LRW influents is one of the most critical and often overlooked aspects of a successful LRW management program**.

4.4.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Include analysis of all major liquid waste inputs on a routine basis.
   - Sample plant sumps and collection tanks feeding the processing system on a routine, scheduled basis, and following unanticipated liquid inputs.
   - Evaluate data obtained from sampling to identify unwanted source(s) of liquid waste.
2. Carefully evaluate sample type and frequency required for each waste stream. The frequency should be defined by the volume generated and the potential for impacting influent collection tank activity and/or chemical characteristics. When considering these program elements, factors to address include:
   - Expected waste stream characteristics.
   - Individual waste stream impact on liquids combined in collection tanks.
   - Types of liquid process to be used.
   - Typical waste stream influent volume and input rate.
   - Significance of chemistry parameter on process performance.
   - Available analytical equipment and resources. On-line instrumentation that is *credible* provides an excellent tool for operators to use for monitoring system performance.
   - Anticipated quality or volume transients.

EXAMPLE: A sump that produces 5,000 gallons per day of relatively pure, low activity liquid does not require the level of attention that a sump producing 100 gallons per day of low quality or high activity liquid waste from a variety of sources.

3. Routinely analyze system influent for:
   - Activity (isotopic)
   - If possible, insoluble activity
   - pH
   - Conductivity
   - Total suspended solids (TSS)

  – Total organic carbon (TOC)/oil and grease

  These basic data should be used to evaluate media and/or process configuration changes to improve media throughput and effluent quality for recycle or release.

4. Sample and review analyses results as soon as possible, preferably as follows:
   – **System influent** - prior to process system startup, facilitating appropriate process component configuration changes based on identified impurities.
   – **System effluent** - as soon as possible following at least one system volume turnover. Maximum within one hour of process startup to verify satisfactory performance.
   – **Individual component or vessel performance** - weekly or as appropriate based on overall system performance and influent quality.
   – Following any known system or influent transients - influent and effluent samples – immediately.
5. Reliable, state-of-the-art in-line monitors have been effective in providing readily available field information to system operators and the plant chemistry staff.
   – Retrofitting this technology into existing systems is typically not cost effective.
   – In-line monitors results in additional instrumentation calibration and maintenance efforts.

> **KEY CONSIDERATION:** Control of influent water quality is an important element of a successful liquid waste management program. The previously recommended improvements offer opportunity for improved process performance, waste volume and cost reduction, do not require large expenditures, and do not require additional staff.

4.4.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. “Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations”, 1993.
2. EPRI. “Filter Demineralizer Performance Improvement Program”, 1996.
3. EPRI. “Preventing Biogassing in Low Level Waste”, TR-111019, 1998.
4. EPRI. NP-4946-SR, "BWR Normal Water Chemistry Guidelines”, 1987.
5. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant”, 1989.
6. EPRI. TR-1009558, “Evaluation of an Alternate, Advanced Filtration Media for Radioactive Liquid Processing”, August 2004.

7. EPRI. TR-1003432, "PWR LLW Test Facility at Surry, Phase III: Process Evaluation and Brine Management", May 2002.

8. EPRI. TR-1003428, "Vibratory Shear Enhanced Process Filtration for Processing Decommissioning Wastes at Rancho Seco", December 2003.

9. EPRI. TR-1003063, "Performance Evaluation of Advanced LLW Liquid Processing Technology: Boiling Water Reactor Liquid Processing", November 2001.

10. EPRI. TR-1002761, "A Review of Ultrafiltration for Liquid Radwaste Processing Systems", -November 2003.

11. EPRI. TR-1000848, "PWR LLW Test Facility: Interim Report on RO Optimization", Nov 2000.

12. EPRI. TR-109444, "Analysis of Advanced Liquid Waste Minimization Techniques at a PWR: Advanced Media, Pleated Filters, and Economic Evaluation Tools", March 1998.

13. EPRI. NP-7386-V3P2, "Radwaste Desk Reference: Volume 3, Parts 1 and 2", May 1994.

4.5 Program Element: Waste Segregation

4.5.1 Program Impact

Commingling low quality (burdened with relatively high concentrations of soluble and/or insoluble impurities) and high activity liquid wastes prior to processing may negatively impact processing performance. Low quality liquid will more rapidly deplete processing media and foul filters and membranes and normally results in increased concentrated solids requiring disposal. Several chemical species present in low quality liquids will result in radioactive isotopes being "thrown" from process media. Additionally, the sludge generated from low quality liquids can be more cost effectively processed if the activity concentration is kept as low as reasonably practical.

As a result, segregation is a useful tool for enhancing process system performance at minimal cost. Installed systems or low technology processing options can be significantly less expensive than advanced processes such as demineralization and membranes. An alternate routing and collection configuration via existing piping and components can also positively impact processing system performance.

> **NOTE:** Some stations that do not recycle system effluent have found that commingling and maintaining a consistent influent stream helps to maintain satisfactory effluent quality.

INDUSTRY EXPERIENCE 1: Processing 500,000 gallons of low quality LRW using filtration and demineralization at an all inclusive cost to the station of $0.25 per gallon, results in a total cost of $125,000. Segregation and use of low technology processing to meet minimal system effluent quality standards could decrease that cost by $0.10 per gallon for a total cost of $50,000 for that volume. This results in a direct savings of $75,000 for the same process volume.

INDUSTRY EXPERIENCE 2: Processing 500,000 gallons of high quality LRW using filtration and demineralization at an all inclusive cost to the station of $0.25 per gallon, results in a total cost of $125,000. Processing low quality liquids at a reduced media throughput, could increase the all inclusive process cost to $0.35 per gallon for a total cost of $175,000. This results in a direct cost increase of $50,000 for the same process volume.

4.5.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

CAUTION: The following recommendation involves reconfiguring systems, or alternate uses of existing systems. The station should carefully review UFSARs, Licensing documents and release permits prior to implementing this guidance to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance. Additionally, an industrial/ personnel safety evaluation may be warranted.

1. Review existing system configurations to identify potential waste segregation schemes. As part of the review and analysis, consider the following:
   - Physically split existing process systems.
   - Use of “retired” tanks or processing components for waste segregation and processing.
   - Isolation or designation of portions of an existing system for use with another waste stream (i.e., dedicating one equipment drain tank for floor drain wastes).
   - Procedure modification and operator training to address segregation.

4.5.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

2. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

3. US DOE. DOE/LLW-144, "Guidelines for Mixed Waste Minimization", 1992.

4. EPRI. NP-7386-V41995, "Radwaste Desk Reference Volume 4: Mixed Waste".

4.6 Program Element: Alternatives to Processing

4.6.1 Program Impact

Liquid radwaste processing influent quality can be dramatically improved at minimal cost through the use of process avoidance. Low quality, low activity liquid wastes can often be released following sampling and/or in-line monitoring without unreasonable increases in effluent activity.

4.6.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

> **CAUTION:** The following recommendation involves potential plant liquid effluent characteristic changes. Regardless of the activity acceptance criteria and ability to meet that using this recommendation, the station should carefully evaluate the impact of this recommendation on the plant liquid release dose.

1. Similar to liquid volume minimization recommendations, explore alternate collection and routing for low quality, low activity liquids. Portable collection containers, laundry systems and decontamination solution tanks frequently provides an acceptable path for collection, sampling and continuous monitoring during release, without normal processing.

4.6.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

3. EPRI. Waste Logic™ software programs and user manuals.

4. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

4.7 Program Element: Planning, Work Control and Outage Success

4.7.1 Program Impact

Planning and work control are the most critical elements of successful outage liquid waste management - understanding in advance the projected waste sources and volumes can lead to successful waste management. The most common measurements for determining the success of an outage are the number of outage days, number of tasks completed, outage cost, and personnel exposure. However, the volume of outage liquid processed, the resultant process effluent quality, and the resultant solid waste volume are effective parameters for assessing outage radwaste controls. Developing outage specific goals for these parameters clearly communicates processing program objectives and typically improves "buy-in" from other organizations. To achieve success in these areas it is paramount that many of the concepts in this document be considered and implemented well in advance of planned outages.

Outage evolutions typically generate significant volumes of waste containing high levels of solids and chemical and activity impurities. Liquids generated by system maintenance, cavity draining, decontamination, tank and sump desludging, media changeouts and routine housekeeping all contribute to the impurity and solids challenge forwarded to the radwaste system. When combined with the high liquid waste volumes associated with plant shutdown and startup, the challenge to liquid processes can be significant.

Therefore, it follows that planning and work control are the most critical element of successful outage liquid waste quality management - understanding in advance the projected waste characteristics (and volumes) can lead to successful waste segregation, processing and effluent management. <u>The most successful programs have found that proceduralized work control queries and work activity and schedule logic ties providing accurate and comprehensive task specific program guidance, are critical elements of outage planning and execution.</u>

That guidance provides information that addresses when the liquid will be generated, how much will be generated, where the liquid should be routed (inventory and process control), and how it should be dispositioned. The goal is to minimize the challenge to media, and impact on inventory, effluent quality, and unit return to power. Early (six months or more) and consistent (all outage planning sessions) involvement and aggressive interaction between key station organizations is critical for optimizing outage processing strategies. Equally important are planning considerations for major projects such as chemical system/component cleaning, chemical decontamination, and major component replacement.

Even the most well planned outages remain dynamic in nature, with unexpected issues driving changes to both schedule and scope. As such, a successful outage LRW plan requires flexibility and deviations in process strategies. Additionally, at many stations, dedicated LRW processing experts (one per shift) acting as processing control coordinators has proven to be extremely successful. The individuals are stationed in the central outage work control center. There they provide continuous outage schedule and work plan compliance oversight, coordination of planned LRW generation, processing, and disposition activities, and evaluation and management of emergent challenges.

Another critical aspect of successful outage management is to ensure that lessons learned are accurately documented and incorporated into future outage work plans. Frequently, the outage water control expert position also provides immediate feedback and direction for resolving emergent processing issues and can capture and evaluate lessons learned feedback.

The combined benefits associated with a detailed and integrated outage processing plan, specific outage processing goals, and consistent, high quality oversight include:

- Minimization of the challenge to processing media and effluent quality.
- Minimization of liquid waste requiring processing and discharge.
- Improved coordination between system draining requirements and start of maintenance activities.
- Better ALARA coordination between system draining and work activities. In some instances, primary system draining may be scheduled after completion of work in an area to minimize the dose rates in certain areas of the plant during maintenance activities.
- Minimization of microbiological growth nutrients in liquid waste requiring processing.
- Improved inventory control minimizing the impact on treatment system capabilities and return to power.

Meeting the established goals creates a win-win situation for all parties involved.

4.7.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Involve liquid processing program management in outage planning in the initial planning phase.

2. Research historical data and identify waste stream characteristics for all planned liquid volumes.

3. Develop a processing strategy that takes into account the following:
   - Anticipated volume.
   - Typical chemical and activity characteristics.
   - Best possible input schedule window.
   - Optimum treatment method.
   - Minimization techniques.
   - Outage scheduling.
   - Drain to mid loop and refill sequencing.
   - Alternatives to processing.
   - Processing support requirements including labor, equipment and materials.
   - Establish progress reporting and feedback method for status and results.
   - Include contingencies for unexpected situations.

> **INDUSTRY EXPERIENCE:** If the RCS remains filled during the outage, there may be settled or suspended particulate activity remaining in the coolant volume in areas with low residual heat removal flow. This can result in higher activity levels in the wastes systems subsequent to coolant recirculation pump startup and unit return to service.

   - Particulate activity, if possible.

4. Consider options for pretreatment of liquids prior to their introduction to "normal" collection tanks.
   - Prefilter cavity drain water at the source to minimize the introduction of crud to the waste system piping, sumps, and/or tanks.

> **INDUSTRY EXPERIENCE**: Several stations have designed portable filter assemblies for filtering cavity drain water at or close to the source. This technique results in improved influent LRW tank quality. A parallel benefit is realized by the reduced potential for crud deposition in downstream piping, sumps, and tanks.

   - Use portable, wheeled filter assemblies for processing sump sludge waste.

4.7.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

4.8 Program Element: LRW Resulting From Process Media Handling

4.8.1 Program Impact

Impurities and solids are introduced into waste processing streams as a result of carryover from decanting phase separators, carbon vessel backwashing, new and spent media sluicing, and from high integrity containers (HIC) during dewatering evolutions. The average particulate size that is backwashed can be physically smaller or colloidal because of the lack of precoat media to assist in charge neutralization and settling, and therefore will probably be more transportable in decant liquid.

URC systems are used at a few stations for condensate deep bed resin cleaning. A similar challenge arises from the backwash liquid generated by non-precoat filters in either LRW or condensate polishing systems; this is typically more significant for high iron plants. During cleaning or backwashing evolutions, the hydraulically separated particulate and/or resin fines are routed to a waste water recovery system in a water slurry for additional treatment and disposal. As a result of the suspension of undesirable waste products transported from either of these processes, the system influent liquid is generally a low quality waste. This presents a substantial impurity challenge to waste processing systems, which results in the generation of additional solid radwaste or reducing the effluent product quality.

An additional challenge is presented by microorganisms capable of acid and biogas production captured in the resultant solid RW. If the solid RW contains significant levels of cellulose and other nutrients, biogassing is likely.

4.8.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Consider the use of chemical treatment to enhance the settling properties of condensate polishing related liquid wastes. This technique is successfully employed at a number of stations.

- Coagulants (copolymers - a chemical reaction in which two or more molecules combine to form larger molecules that contain repeating structural units) have been effective at agglomerating particles, enhancing their settling efficiency.
- Bench testing is recommended to identify the optimum copolymer and dosage.

INDUSTRY EXPERIENCE: Many stations have found that the required dose varies by influent batch. Bench testing is recommended to identify the optimum copolymer and dosage. Additionally, several copolymers may be required for varying conditions. Refer to the section titled "Influent Liquid Pretreatment" for additional detail regarding this option.

2. Establish a program for segregation and alternate processing of low-quality media transfer and decant liquids.
   - Partially depleted media in a HIC as an atmospheric demineralizer for decant wastes has been successfully demonstrated at several utilities. This provides preprocessing prior to routing the waste to installed plant systems, without generating additional solid waste.
3. Use a smaller mesh dewatering screen or progressively decreasing micron rating for lateral filters in the waste processing HICs. This would minimize particle carryover to liquid waste collection tanks during container dewatering evolutions.
4. Route decant liquid wastes back to the spent resin tank to the extent practical. This practice increases the potential for additional decay of short lived nuclides, additional ion exchange, and solids transfer to the next waste package loaded.
5. Carefully evaluate and consider the use of coagulants/polymers in BWR phase separators to agglomerate iron and solids generated using minimum and non precoat elements. This process has the potential to improve phase separation, generating an improved quality decant liquid.
6. Route this waste stream to a separate collection tank for processing using alternate methods as described in Sections 4.3, 4.7, 4.8, 5.6 and 5.7, or using other viable techniques.

4.8.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.
2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.
3. EPRI. Waste Logic™ software programs and user manuals.
4. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

5. EPRI. “Preventing Biogassing in Low Level Waste”, TR-111019, 1998.

4.9 Program Element: Mop Water

4.9.1 Program Impact

At some stations, floor and equipment surfaces in the RCA are routinely cleaned, decontaminated, and/or stripped and waxed using commercially available solutions. Frequently, mop water, decontamination solutions, and stripper are disposed of directly into floor drains. These solutions, though normally low activity, are typically high in solids, organic materials, and cleaning agents that can result in premature depletion of ion exchange media, membrane and filter fouling, and increased foaming and carryover in radwaste processing evaporators

> **NOTE:** Cleaning agents can actually promote the transport of organics and activity to the radwaste system. Some cleaning agents will actually complex organics and activity into “non-ionic” species making them more difficult if not impossible to remove with normal processing techniques.

4.9.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Evaluate and implement the use of alternative methods for releasing waste mop liquid. Collect and process mop water as a separate waste stream. This could be accomplished using one of the following options:
   - Use an installed tank such as a laundry or decontamination solution tank as a mop waste collector for filtration and release bypassing other more costly processes.

> **CAUTION:** Drums used for evaporation should be properly ventilated to preclude concentrating noxious fumes that may create an inhalation hazard. An industrial safety evaluation may be warranted.

   - Evaporate low quality cleaning liquids using electric drum heaters located under a ventilation hood.
   - Configure a HIC containing partially depleted (preferably low activity to minimize personnel exposure) processing media as an atmospheric demineralizer to process the low quality waste liquid. Figure 4-1 contains a simplified diagram of this concept.

NOTE: If the spent media is going to be volume reduced off site using a pyrolysis technology, evaluate the shipping cask Certificates of Compliance (C of C) and site procedures for HIC liquid volume limitations. If acceptable, consider adding the mop water to the HIC **after** gross dewatering is completed. The low quality liquid is then shipped with the media for VR, and can be used as a sluice medium by the off-site VR vendor.

INDUSTRY EXPERIENCE: One station collects all RCA mop water in a plastic holding tank. It is recirculated through a HIC containing about 70 ft^3 of charcoal until it meets release permit Oil and Grease limitations. This minimizes the impact that detergents and chemical cleaners have on membranes or ion exchange media.

– Clearly labeling all collection containers for their intended use. It is also a good practice to include on the label, those inputs not permitted in the collection container (i.e., lubricants, residual chemical waste etc.).

2. Mop water generated at RCA access and egress areas should be disposed as radwaste to preclude concentration of trace contamination in sewage treatment facilities.

3. Eliminate chemical cleaners for routine mopping. Reserve cleaning agent use only for those applications where it is required to breakdown lubricants or heavily soiled areas, dispensing only the minimum volume required.

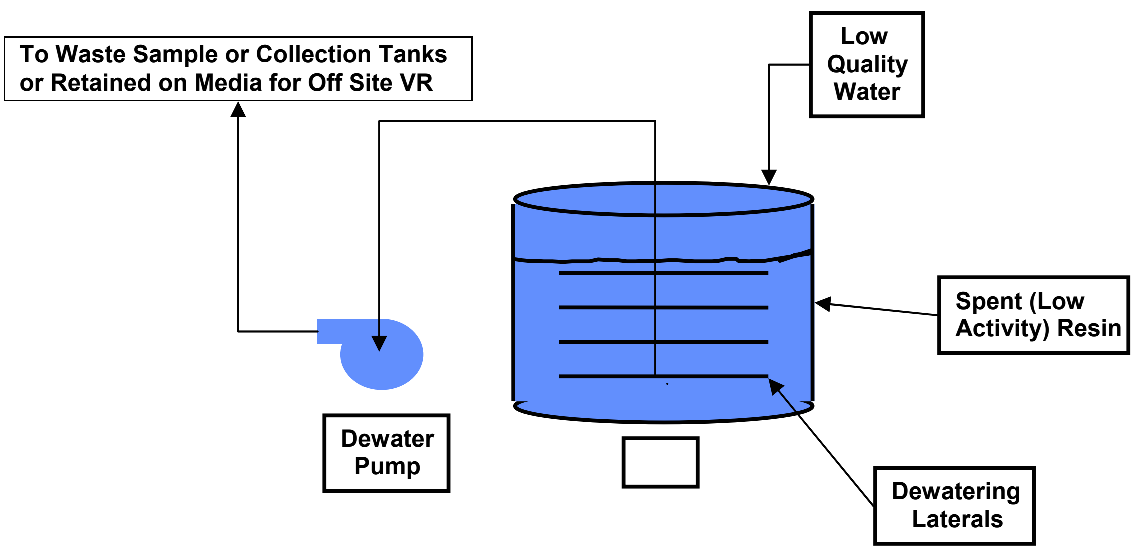

Figure 4-1
Low Quality Liquid Waste Processing:

4.9.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

4.10 Program Element: Organics

4.10.1 Program Impact

Regardless of the materiel condition of a station, sumps typically concentrate some volume of oil, EHC fluid, or glycol. The fluids are introduced to the radwaste processing system via component seal leakage, larger volume spillage, or frequently during fluid addition to components as a result of improper addition containers or devices. As a result, the fluids can be emulsified during sump or collection tank pump operation and forwarded to the radwaste system(s). This is especially true if liquid is being introduced at the same time the pump is actually in operation. These fluids negatively impact processing operations and effluent liquid quality.

This factor is typically more significant for stations using membrane technology or recycling system effluent for use in the reactor coolant system.

4.10.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Identify and eliminate or minimize organic laden inputs to sumps and collection tanks.
   - Consider establishing a small task force or dedicate a specific team to effect repairs of oil leaks and for optimizing lubrication management.
   - The team should, as a minimum, consist of support from the Operations, Maintenance, and Engineering organizations.
   - Empower the team to ensure plan follow through once the effort is started.

> **INDUSTRY EXPERIENCE**: One large BWR station had implemented all economically feasible oil control measures, but experienced some minor oil inputs to equipment drains primarily from pump bearing lubrication misting. The station installed commercially available oil separators (viscosity based separation, milk can type) at each pump pedestal. All liquids from the pedestal are routed through the separators prior to input to drain collection systems.

2. Develop and implement an oil/EHC/glycol control program. The fluids should be tracked from warehouse issue to component addition, removal, or replacement (changeout/PMs).

This will result in relatively accurate fluid volume tracking, fluid system/seal performance monitoring, and more rapid identification of abnormalities.

3. Install portable mechanized oil skimmer systems on sumps that routinely experience oil input. These inexpensive skimmers are used successfully at several utilities for consistently troublesome sumps and do not create additional waste during the separation process. One station resolved "splatter" problems with the tubular type of skimmer by encasing the tygon tubing in a large diameter PVC pipe sleeve from the skimmer to the top of the sump.

> **CAUTION:** Floating oil absorbent pads in sumps generate additional solid radwaste that requires disposal. The floating pads can potentially result in sump level switch or pump malfunctions. Additionally, at least one type of pad can leach chemicals integral to the pad design that are forwarded to downstream processing components.

4. Use oil pads on oily water separators to remove residual surface oil.

5. Work with operations and maintenance personnel to evaluate and procure the correct fluid addition devices. Small polyethylene squeeze bottles available in commercial laboratory supply catalogs has been successfully implemented at some stations to add lubricants to plant equipment.

6. Consider replacing cellulose containing absorbent materials with non organic alternatives.

4.10.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

3. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

4.11 Program Element: Laundry Waste

4.11.1 Program Impact

The majority of plants does not launder protective clothing (PCs) on-site and therefore do not generate liquid laundry waste. They have opted for contracted vendor cleaning at an off-site facility or switches to single use PCs. A few stations use on-site contracted vendor cleaning, generating some laundry waste that requires additional processing prior to recycle or release. Finally, a very few number of plants operate installed laundry equipment, typically for specialty cleaning including rubber garments to complement single use PCs, mops, or waste collection bags.

When generated on-site, liquid laundry waste may contain concentrated solids removed from laundered materials, fabric lint, and organic based laundry cleaning solutions. If combined with other liquid waste, this impurity loading will negatively impact liquid processing operations, possibly resulting in more rapid filter and/or membrane fouling, more rapid ion exchange material depletion, or foaming and carryover of impurities in evaporator effluent distillate.

4.11.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Carefully evaluate the cost benefit of on-site laundry operations. As part of that assessment, consider the following issues:
   - Impact costs for liquid processing - labor, media costs, packaging and disposal.
   - Labor to sort, clean, monitor and re-sort/fold laundry items.
   - Equipment replacement component costs, maintenance labor and monitoring calibration/source checks.
   - Impact on processing system effluent quality and activity.
   - Alternate use of facility or space occupied by laundry equipment.
   - Radiological controls costs - labor, materials, radiological hazard potential.
   - Alternate use of staff required for process.
2. Require on-site laundry contractors to minimize liquid volumes, optimize pretreatment prior to transfer of liquids to the station (e.g., thermal treatment), and the use of cleaning solutions that do not negatively impact plant specific liquid processes.
3. Use alternate on-site laundry process technologies such as ozone cleaning.
4. Segregate the waste stream for alternate processing, typically high micron filtration without demineralization.
5. Maintain laundry waste stream strainers intact to prevent fouling downstream processing media/components.

4.11.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.

2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.
3. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.
4. EPRI. NP-7309, "EPRI Guide to Managing Nuclear Utility Protective Clothing Programs", 1991.

4.12 Program Element: Precipitation, Exterior Moats and Ground Water

4.12.1 Program Impact

These waste streams are typically not radioactive, but are typically high in soluble and insoluble impurities. Water collected in exterior moats and sumps (often associated with tank farms), is typically high in impurities including biological matter, calcium, and sodium that negatively impact processing operations. They can rapidly deplete normal processing media and can also promote microbial growth. At several stations, analysis of ground water indicated the presence of significant amounts of calcium, most probably a result of structural concrete leaching or groundwater intrusion. Additionally, ground water intrusion can be incorrectly identified as the source of undesirable inputs, masking other sources of low quality LRW generation. Many stations address this waste with administrative guidance permitting sample and release without processing. The most successful stations have recognized the financial liability associated with processing these wastes and have implemented aggressive in-leakage prevention programs, identifying and deploying the resources and technology required to mitigate intrusion.

4.12.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Minimize the volume of rain water that requires processing.
   - Identify and repair all roof leaks.
   - Implement proceduralized periodic inspections for roof leak identification. This can be accomplished through surveillance test or PM program incorporation.
2. Identify and repair ground water (structural) leaks. Several stations successfully use sealant injection contractors to minimize or eliminate ground water intrusion.
3. Eliminate the source(s) of exterior moat contamination and/or decontaminate the moat as necessary for free release, eliminating the need for routine processing for this waste stream.
4. Leakage that cannot be eliminated should be contained for collection, sampled and free released without processing if appropriate.
5. Investigate and reactivate, as appropriate, exterior construction curtain drain sumps to pump liquid away from plant structures.

4.12.3 Cross Reference(s):

1. This report: Section 3.4 - Leak Repair and Prioritization
2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.
3. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

4.13 Program Element: Miscellaneous Secondary System Waste

4.13.1 Program Impact

Uncontrolled leakage and draining of liquids from these systems can present a ***major burden*** on LRW processing media including ion exchangers and membranes. This water contains organic material used for the corrosion treatment, dissolved solids (such as nutrients) and other impurities. These shorten the service life of ion exchange resin, filtration media, and membrane materials, and increase operating LRW program costs. Additionally, for recycled water, they can negatively impact both LRW system effluent quality and subsequently feedwater chemistry.

> INDUSTRY EXPERIENCE: One station has successfully reduced the impact of low quality liquids using an input identification matrix. The matrix provides chemical and radioisotope characteristics for easy identification of processing system influent sources. The table contains a matrix similar to the example in Table 4-1.

Table 4-1
Sample input identification matrix

Source	pH	Conductivity	Chemical Tag	Radioisotope
RCS [1]	5.5	25-35	None	High ratio (Co 58/60)
Service Water	8.4	1,790	Chlorides 450 ppm	None
Chillwater	9.0-9.1	4,000	Nitrites 500 ppm	None

NOTE 1: The matrix should include normal RCS parameters for use when comparing data or commingling waste streams in sumps and collection tanks.

<u>CAUTION</u> 1: Several of the following considerations involve reconfiguring systems, or alternate uses of existing systems. The station should carefully review UFSARs, Licensing documents and release permits prior to implementing this guidance to ensure regulatory compliance. A 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance. Additionally, an industrial safety evaluation may be warranted.

<u>CAUTION</u> 2: Several stations use yard drains for releasing secondary waste streams following chemical and radioactivity analyses. The station should carefully review bulk sample procedures, UFSARs, licensing documents, and release permits prior to implementing this practice. The review should verify regulatory compliance with processing and continuous monitoring during release definitions and requirements. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

<u>CAUTION</u> 3: Several stations route these wastes directly to effluent monitor tanks for recirculation, sampling and analysis, and monitored release via established plant procedures and pathways. Many stations' licensing documents, UFSAR, or procedures require specific treatment or processing for ALL wastes released from the site. Direct routing to an effluent tank without treatment or processing would not be an acceptable option for those stations.

4.13.2 Guidance - Service Water

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Similar to the guidance provided in Section 3, if permissible by plant UFSAR, licensing documents, and procedures, establish drain paths for releasing the waste water without processing. The liquid should be sampled and/or continuously monitored (**<u>preferred</u>**) during release to ensure compliance with plant effluent requirements.

INDUSTRY EXPERIENCE: At least one station uses the negative pressure created by service water pumps to vacuum drag water from the header isolated for work to the header currently in service. This allows rapid water movement and no secondary waste is created.

2. Perform an analysis using corrosion inhibitor addition logs and makeup water addition rates, to identify system leakage.

NOTE: Warehouse issuance of corrosion inhibitor may be misleading as that typically includes all stock issued, but not necessarily added to the system to date.

3. Similar to recommendation 2, perform the same analysis for biocides used for treating the liquid stream.

4. Use chemistry data to develop a plant specific input identification matrix for secondary waste streams. The matrix should include normal RCS parameters for use when comparing data or commingling waste streams in sumps and collection tanks.

4.13.3 Guidance - Closed Cooling System Waste

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Establish water management plans based on required maintenance or performance testing to optimize treatment and/or disposition practices.

2. Collect and recycle as much of the generated volume as practical.

CAUTION: The cooling water should be sampled to determine chemical and/or microbial content, and its reuse approved by the chemistry organization.

4.13.4 Guidance - Fire Protection System Waste

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Evaluate periodic system flush requirements versus benefit derived. Consider reducing the flush time to minimize LRW generation. Clearly define the required header flush times in the field implementation procedures.

2. Consider the use of high quality water in fire protection systems to minimize nutrient inputs into LRW.

3. Use component specific fittings and hoses to route flush water to clean waste headers or release monitor tanks, bypassing normal LRW processing.

4.13.5 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

2. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

3. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

4.14 Program Element: Sumps and Tank Cleaning

4.14.1 Program Impact

As previously discussed, sumps and tanks are concentration points for many undesirable waste inputs. They can accumulate oil, solids, and a variety of chemical species, including organics. When LRW processing systems are challenged by waste having these characteristics, it can result in:

- Decreased processing media throughput.
- Increased solid waste volume.
- Increased personnel exposure.
- Increase program costs.

It is known that some of the inputs such as oil and solids are not easily transported by sump or tank liquids as a result of differing material densities. However, pump operation or chemical interactions can result in formation of more readily transportable impurities by complexing oils or solids. Routine sump and tank cleaning will minimize that potential by eliminating the undesirable species, thereby precluding their input to the processing stream. These solids are important sources (food) for growth of microorganisms that can result in biogassing. When properly managed, these inputs will have minimal impact on processing system performance, program costs and solid waste disposal volumes.

Additionally, industry experience clearly demonstrates that sludge and the liquid inputs to liquid and solids collection tanks contain chemical impurities that can attack tank welds and wall thickness resulting in failure.

Industry Experience: Several stations have experienced tank failures that were caused by inadequate tank sludge control. (USNRC Information Notice No. 79-007, Rupture of Radwaste Tanks; and 96-14, Degradation Of Radwaste Facility Equipment)

Frequently, plants delay or avoid tank inspections due to the personnel exposure associated with those efforts. Exposure should not be the controlling factor as the level of effort and exposure associated with tank failure, recovery, and repair or replacement could very easily exceed inspection values. Additionally, the personnel and plant safety aspects of premature tank failure far outweigh the negative aspects of inspection related exposure.

4.14.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

CAUTION: The station should carefully review updated final safety analysis reports (UFSAR), Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

1. Use nylon drain socks, equipment draining controls, ground and rainwater intrusion mitigation, and good housekeeping practices to minimize the need for sump and tank cleaning.
2. Inspect and clean as necessary sumps and tanks on a routinely scheduled basis. The best programs use performance based criteria for determining cleaning frequency.

   Several of the criteria used include:

   - Sump or tank dose rates.
   - Process system influent chemistry data.
   - Historical data on solids buildup.
   - Visual inspection by a qualified individual using clearly defined criteria.
3. Sumps and tanks accessible during normal plant operations should be scheduled for cleaning following outages to minimize outage impact and to remove the larger concentration of impurities typically associated with outage work. Initial cleaning evolutions will most likely generate large volumes of solids and other impurities. However, implementation of controls discussed in this document combined with routine cleaning will result in progressively lower volumes of waste generated during subsequent cleaning operations.
4. Using manual overrides to pump tanks down to the pump's minimum operational level.

5. Using installed or portable recirculation systems to ensure the residual heel is turned over on a frequent basis, minimizing solids settling and sludge accumulation.

6. Removing tank's residual LRW with portable pump systems on a periodic basis.

7. When cleaning tanks, the use of remote or extension technology will significantly decrease personnel exposure with satisfactory results. The use of robotic track or hover sparging and vacuum equipment is effective for most tank cleaning. Several utilities own this equipment, others contract robotics vendors for cleaning operations.

8. Sumps can be effectively cleaned by using powerful wet pump-vacuum systems with extension wands, recirculating the pump-vacuum effluent through portable filters back to the sump. This results in solids removal and minimal liquid waste generation.

9. Use installed sump and tank recirculation equipment to routinely recirculate the contents, minimizing solids settling and sludge accumulation.

10. Clean related drains, sumps and tanks prior to installation of alternate, improved, or mobile process technologies.

4.14.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

3. USNRC IN No. 79-007 "Rupture of Radwaste Tanks".

4. USNRC IN No. 96-14 " Degradation Of Radwaste Facility Equipment At Millstone Nuclear Power Station, Unit 1".

4.15 Program Element: Chemistry Sample and Laboratory Waste

4.15.1 Program Impact

Routine chemistry analyses result in the use and disposal of various liquids burdened with activity and/or chemicals. This waste stream adds undesirable species to the liquid waste systems, negatively impacting LRW processing performance.

4.15.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Consider the use of available alternative chemical analysis techniques and methodologies. Research alternatives and where applicable implement new methods.

> **INDUSTRY EXPERIENCE**: At least one station has tested and implemented the use of analytical procedures and techniques that minimize the chemical impact on processing operations. This includes environmentally acceptable scintillation cocktails.

2. Characterize the waste stream and evaluate the use of alternate processing methods for this waste water rather than complete demineralization. The use of filter and release processes such as a laundry waste or decontamination solution system may be appropriate.

4.15.3 Cross Reference(s):

1. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

5
RADIOACTIVE LIQUID TREATMENT TECHNOLOGY AND PROCESS OPTIMIZATION

5.1 Overview

Tank and water management, chemical pretreatment, filtration, separation, ion exchange and evaporation are the primary considerations related to liquid waste processing. The available configurations can vary significantly by application and technology, however, it is fundamentally important to remember that filtration is typically intended to target insoluble species and demineralization soluble species, whereas evaporation is intended for both.

The effectiveness of a processing configuration can change rapidly with variations in influent sources; therefore it is essential that the liquid to be processed is thoroughly characterized prior to selection of a specific process technique. The most successful process schemes require that the waste stream stability be maintained. The general waste stream characteristics that should be evaluated prior to developing a processing strategy include:

- Influent pH.
- Conductivity.
- Particle size and abundance using various techniques.
- Activity (total and isotopic).
- Organic concentration.
- Chemical presence and concentration (i.e., boron, silica, closed cooling water treatment chemicals, etc.).
- Microorganism abundance (“food” supply).
- Anticipated variations in influent quality.
- Process volume.

Defining the performance acceptance criteria for LRW processing is a difficult task. At many utilities those criteria are defined solely by recycle or release criteria dependent on reasonable efforts, while at others processing is complex and costly. In order to define what is “reasonable” processing, several aspects of the program should be evaluated, including the following:

- Liquid processing goals [i.e., recycle or release, reduction in effluent activity or a chemical specie(s), feedwater quality].

- Ability to meet recycle or release criteria and efforts to continually improve process performance.
- Effective holdup capacity.
- Cost of processing versus benefit.
- ALARA impact.
- Waste packaging and handling efficiency.
- Prioritization to ensure easy to resolve issues are dealt with prior to more complex issues.

Following characterization of the liquid waste stream and evaluation of the above issues, a review of available technologies is necessary prior to process technology selection. The available technologies have changed significantly in the past decade by combining nuclear experience and lessons learned, advances in processing materials, and cross-over technology from other industries. This section addresses technologies currently available to the industry.

Several EPRI reports are available that address currently available technologies, their evaluation and selection, and should be consulted prior to finalizing process strategies (see References appendix of this report).

5.2 Program Element: Tank and Water Management

5.2.1 Program Impact

Managing tank capacity and water movement are important elements of successful LRW processing programs. Proper planning can result in maximization of holdup capacity with minimal movement of LRW, and considers routine and surge volumes, and outage inputs. Additionally, tank management programs should consider evaluation of routine removal of liquid “heel” volumes present after pump-down cut-off (e.g., using manual override) to minimize cross contamination (e.g., RCS recycle hold up tank pump down). Refer to Section 5.14 for additional information related to tank cleaning.

5.2.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

CAUTION: The station should carefully review updated final safety analysis reports (UFSAR), Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

1. Review historical data and develop operational and outage holdup capacity management plans. The plans should focus on minimizing processing and water movement and maximizing waste stream segregation. The use of system components and piping outside their original design configuration may result in enhanced program performance.

> **INDUSTRY EXPERIENCE**: One station converted abandoned LRW evaporator condensate tanks to function as monitor tanks for the radwaste ion exchange train.

2. Devise methods and/or procedures to minimize residual waste in tanks following pump-down. These techniques can include:

> **CAUTION:** The use of manual pumping operations requires careful operator oversight to prevent pump cavitation and potential damage. Using manual overrides to pump tanks down to the pump's minimum operational level.

   – Using installed or portable recirculation systems to ensure the residual heel is turned over on a frequent basis, minimizing solids settling and sludge accumulation.
   – Removing tank's residual LRW with portable pump systems on a periodic basis.
   – Manual draindown.

3. To the extent practical, establish plans for unanticipated surge volumes. This minimizes the impact on processing operations.

4. Develop a processing plan during periods of high waste generation such as outages. Incorporate alternates to processing as discussed previously in Sections 4 and 5. Ensure that the strategy addresses utilization of available tankage to maximize decay of short lived isotopes while maintaining adequate reserve volume for unanticipated inputs.

> **INDUSTRY EXPERIENCE**: Several stations segregate problematic waste streams, significantly improving the success of the processing system.
> 1) Waste water following the initial outage crud burst and cleanup is collected and segregated. Extended storage and agitation modify the cobalt state, improving its removal efficiency.
> 2) Waste water with significant levels of hydrazine are segregated and recirculated to allow for the reactive consumption of hydrazine to minimal concentrations.
> 3) Reactor cavity decontamination waste water is collected and segregated. Extended storage and agitation modify the cobalt state, improving its removal efficiency.
>
> This segregated waste is intermittently processed with non-outage waste.

It is important to note that some stations that do not recycle system effluent have found that commingling and maintaining a consistent influent stream helps to maintain satisfactory effluent quality.

INDUSTRY EXPERIENCE: Several stations ensure holdup tanks are emptied prior to the start of an outage, and that LRW management is incorporated in the outage plan. As a result, LRW containing short lived isotopes such as Co-58 can be retained for extended periods for decay, resulting in reduced effluent activity and processing media demands.

5.3 Program Element: Filter Backwash and URC Liquid Waste Management

5.3.1 Program Impact

At BWR stations, condensate polishing prefilter backwash and ultrasonic resin cleaning (URC) liquid wastes can have a significant impact on LRW processing programs. Typically plants employ either prefiltration or URC. The primary constituent in these waste streams is insoluble iron removed from the condensate system. BWR particulate iron is small in size (<2µm) and can be colloidal because of the absence of charged counter-ions. The majority of the corrosion products in a BWR are in the form of hematite, magnetite, and amorphous iron. The percentage of magnetite present in BWR corrosion products is generally small. Magnetite, because of its crystalline structure, is easier to filter than the other forms of iron. Amorphous iron on the other hand, is more difficult to filter and presents long-term filtration problems by strongly adhering to the filtration media. The corrosion products and their concentration can play a major role in determining the performance of filtration systems and LRW processing systems.

Prefilter backwash evolutions result in generation of a liquid waste stream high in solids (iron). This waste is typically routed to a phase separator or backwash receiver where it is retained to allow solids settling. That process step often requires the introduction of copolymers or flocculants to improve the solids settling efficiency. The clarified separator/receiver decant is routed to either the high or low conductivity collection systems for processing as LRW. The settled solids are typically routed to a HIC for dewatering and off-site VR and/or disposal.

URC waste water contains resin fines and insoluble iron removed from the station's deep-bed condensate polishers. Similar to prefilter backwash, the liquid may be routed to a settling tank, or in some plants, it is directly routed to waste processing systems.

Iron laden LRW can foul filter septa, require chemical treatment for settling, reduce the efficiency of waste sludge transfers to shipping liners, foul dewatering laterals, and reduce the efficiency of off-site volume reduction processes. The combination of these factors can result in direct process inefficiencies, labor costs, new materials costs, and waste costs.

Additionally, the variations in liquid and solid phases combined with tank and accumulated sludge geometries make it difficult to accurately determine the sludge level in separators and sludge tanks. This can lead to erroneous sludge volume balances between the estimated filter backwash solid volume, the waste sludge tank, and the volume transferred to transport waste containers. This may lead to a gradual, undetected increase in waste sludge tank level and in a worst case scenario, a tank failure. The sludge accumulation and the associated impurities create a prime environment for weld corrosion at seams and pipe penetrations.

5.3.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

> **CAUTION:** The station should carefully review updated final safety analysis reports (UFSAR), Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance. Additionally, an industrial safety evaluation may be warranted.

1. Review historical data and develop operational and outage holdup capacity management plans. The plans should focus on minimizing processing and water movement and maximizing waste stream segregation. The use of system components and piping outside their original design configuration may result in enhanced program performance.

2. Chemical additives including copolymers and other flocculants can improve the settling properties of solids laden backwash/cleaning waste liquids.

> **CAUTION:** Polymers may result in a waste sludge product that negatively impacts sludge transfer to waste containers and subsequent waste container dewatering operations.

   – Polymer metering (dosing) and residence time is critical to the success of this technique. The correct amount and reaction time should be identified in pilot, laboratory testing.

3. The resultant waste sludge can present challenges to transfer and packaging operations.

4. Determine the backwash iron impact by performing an iron mass balance. This will require laboratory work and handling condensate filter elements. Determine the iron concentration for:

   – filter influent

   – filter effluent

   – demineralizer effluent

   – spent filter element

5. The differential equals the theoretical backwash iron concentration. The backwash liquid volume should then be calculated using installed instrumentation and portable strap on ultrasonic flow meters or equivalent as needed to augment the available data. Use the collective data to determine the volume of solids that should be present in the waste sludge tank.

6. Use that information to determine the need for further corrective actions including waste sludge tank inspection and/or modification.
   - Tank inspections should focus on low or no flow areas that accumulate sludge, weld integrity (NDE), and tank wall thinning instead of design specifications.
   - Modifications that should be evaluated include: improved suction/pump out lines, improved solids level indication, sparging, conical bottoms for improved pump out, and easily removable access ports to facilitate future inspections.
   - The tank should be inspected for weld integrity at joints and pipe penetrations.
   - Tank inspections should be performed using remote technology. Organizations with significant industry experience and proven remote tooling tailored specifically to this task will result in a cost and exposure efficient, high quality inspection campaign.
   - Evaluate an advanced solids collection technology for more efficient dewatering of the waste sludge. These components are designed specifically for difficult to dewater waste streams.
   - Evaluate the use of a new, minimal precoat on the liner dewatering laterals. This technique has been successfully employed at other stations. This method minimizes the direct fouling of dewatering laterals by solids and allows the laterals to be air/water bumped when dP increases, which extends their useful life. This technique requires approval from the waste container manufacturer prior to use.
   - Alternatively, the most cost effective solution may be pumping waste sludge directly to a previously gross dewatered liner of spent condensate bead resin. The entire waste volume (liquid and solid) remains in the liner and can be shipped directly off site for thermal volume reduction. This would require:
   - Approval from the vendor.
   - An evaluation of the shipping cask C of C to determine if the residual liquid is compliant with that document.
   - A review of the station PCP and procedures.
   - This would eliminate waste sludge shipments as all waste would be shipped with existing condensate resin waste.
   - This eliminates labor intensive waste sludge liner dewatering operations.

5.3.3 Cross Reference(s):

1. EPRI. TR 1002889, “Condensate Polishing Guidelines for Pressurized Water Reactor and Boiling Water Reactor Plants – 2004 Revision”, March 2004.

5.4 Program Element: Influent Liquid Pretreatment

5.4.1 Program Impact

Chemical addition, ultraviolet (UV) treatment, and ozone injection are the predominant liquid waste stream pretreatment options. Their use can improve filtration and ion exchanger performance and effluent quality, and result in reduced solid waste generation. Additionally, chemical pretreatment such as copolymer injection has proven to be effective for improving particulate settling for phase separation. The success of pretreatment applications is typically specific to the waste stream characteristics, application oversight, and technology deployed.

Two of the most predominant chemical pretreatments are pH adjustment and copolymer addition. Their success is highly dependent on accurate liquid characterization (ionic or particulate, particle size, etc.). In some applications, reduction of pH can convert complexed and colloidal metals into a soluble form increasing the overall effectiveness of organic ion exchange media. Similarly, copolymer addition can convert some forms of colloidal metals into a species that can be removed by organic ion exchange resin. Other copolymers coalesce colloidal metals into larger particles, improving their filterability by layered carbon beds. The chemical injection point is critical to the success or failure of the liquid waste processing system, vendor or other expert guidance will assist with optimizing the design.

One other pretreatment option involves extended recirculation of atmospheric tanks. The recirculation process results in oxygenation of the liquid waste. This can impact particle's ionic state and size, resulting in improved process DF.

> **INDUSTRY EXPERIENCE**: Several stations ensure that atmospheric holdup tanks are recirculated for at least 24 hours prior to processing or are recirculated daily over an extended period of time (several weeks). This oxygenation process has resulted in significantly improved Co-58 and Co-60 removal efficiencies.

5.4.1.1 Chemical - Dosage, Addition Options, and Interface Time

Chemical additions are designed to enhance the removal of soluble ionic species by standard and ion specific exchange media and the removal of colloids by filtration. Determining the optimal chemical dose, injection rate, and chemical to liquid interface time can be accomplished via testing based on waste stream characteristics, industry experience, and chemical supplier data. Bench top visual observation and/or column testing can provide rapid and relatively accurate data that can be used for scaling up to in-plant process application. For filtration enhancement options, the use of plant filter media samples (provided by the filter vendor) is a very effective method for laboratory assessment of the process efficiency improvement.

Laboratory testing typically involves obtaining representative samples of the subject waste stream and through analysis, defining its chemical and activity characteristics. Then based on chemical manufacturer recommendations and industry experience, one or more chemicals may be added to one or more samples and blended. Following a recommended interface period, the modified waste stream may be evaluated for settling, or processed through test media. The test column(s) effluent product and/or test media is analyzed to determine if pilot test goals were met. Using the most successful results, the pilot testing is scaled up to a full process batch.

Many stations have plant design considerations that limit the options for chemical injection. Existing plant instrumentation, drain, or vent taps can often be used for injection points. In some instances, system or component modifications may be required to facilitate chemical addition. Typically static, in line mixers or tank spargers or recirculation lines are used to ensure a homogenous mixture is created. When using copolymers consider that injection upstream of pumps can result in shearing the flocculant, reducing the overall effectiveness of the process.

5.4.1.2 Automated Injection

Several vendors offer automated systems that measure the electrical charge using a streaming (SCD), and/or evaluate particle size and distribution in liquids using similar techniques. Following initial manual sampling and analysis, the initial unit settings are determined. Using that data, the unit dispenses chemical additives using an automated metering system. An additional feedback system can analyze the downstream parameters that are used for automated metering adjustment. The entire processing package typically includes a combination of filtration, ion exchange and chemical treatment technologies. The automated monitoring and injection system establishes and maintains the most efficient additive concentration.

> **INDUSTRY EXPERIENCE**: One station using an automated metering system in conjunction with other process improvements was able to achieve average system DF improvements of 10% - 30%.

> **INDUSTRY EXPERIENCE**: Automated injection systems typically require careful oversight to maintain the equipment calibration, precluding over dosage of chemicals.

5.4.1.3 pH Adjustment

The pH of a waste stream can have a significant impact on effluent product quality, media throughput and subsequently, secondary waste generation. In a normal cation/anion process, the cation media exchanges metal ions for hydrogen ions, resulting in a reduced pH. Ideally, the anion component results in a pH swing back to a near neutral value. Fluctuations in influent pH can result in inadvertent regeneration of media due to the media ionic preference (selectivity) relative to the type and concentration of influent ions.

Under conventional processing methodologies resin induced pH swings can be significant, affecting performance of downstream beds. This can require frequent re-sequencing of beds to minimize the impact on downstream vessel performance. When using chemical pretreatment, pH swings can create chemical conditions outside the optimal range for organic media, and can result in acid wash, sloughing and poor performance.

In an effort to more carefully control demineralizer decontamination factors and media throughput, stabilization of influent waste water pH through metered injection of NaOH has been successfully used at some plants.

INDUSTRY EXPERIENCE: At one station, to address the affect of pH swings, the influent stream pH is monitored by an in-line probe to control NaOH injection, which maintains the influent pH at 7.0. Sodium form cation resin is used, replacing the traditional hydrogen form cation, precluding pH swings downstream of a chemically active bed. Anion resin, when required, is placed at the end of the system to minimize the impact of a pH swing on the system. To restore pH to meet release limits, acid injection is used on the effluent when a chemically active anion is in service.

In this environment, cesium tends to be weakly bonded to the sodium form cation resin. The sodium form cation is operated past cesium break to cobalt break. Downstream of the sodium form cation, a synthetic cesium selective zeolite is used for cesium removal. It is operated past cobalt break to cesium break. This processing methodology is effective for 90% of that plant's waste water.

Typically, 90% of that plant's LRW processing problems result from 10% of the plant's inputs. In particular, resin sluice waste frequently presents cobalt in a fine particulate state or in complexes that pass through the system unaffected by demineralization or filtration. These inputs are sometimes effectively treated by isolating the liquid and reducing the pH to less than 5.0. The LRW is recirculated for a minimum of 24 hours allowing cobalt to return to a soluble state. This improves the ion exchange efficiency during subsequent reprocessing operations. Similar to all LRW influent streams, the pH is maintained at 7.0 as it enters the processing skid.

The cumulative effect of this treatment methodology has resulted in greatly improved media throughput, reduced processing costs and standardized treatment methods.

Typical performance for the station in the previous example is listed below:

Table 5-1
Typical performance for plants that have implemented pH control

Media	Throughput (Gallons per ft3)
Carbon	55,000
Hydrogen form cation	70,000
Sodium form cation	90,000
Cesium specific	250,000
Anion	50,000

5.4.1.4 Colloidal Cobalt Control

Cobalt has historically been difficult to remove because of its number of oxidative states (both cation and anion) and weakly ionic characteristics. Cobalt-58 has proven to be difficult to remove from LRW streams because of its varying physical states including particulate, colloidal, and ionic. Additionally, those states appear to be affected by plant operating modes including full power and shutdown conditions.

5.4.1.5 Copolymer Addition

Historically, copolymers has been effective for the treatment of high cobalt-58 liquid waste streams. The addition of small amounts of low molecular weight cationic polyelectrolyte has been able to convert troublesome colloidal cobalt into a species that can be removed by organic cation resin. The copolymer is typically injected into the subject LRW stream upstream of the carbon filter vessel, versus directly into the influent waste collection tank. A delay time is required between the injection point and the process media for adequate mixing and reaction. The specific value is calculated using time, influent piping and hose length, system flow rate, and manufacturer recommendations.

INDUSTRY EXPERIENCE 1:
One station created a delay coil using the flexible hoses that are used to interconnect the vessels. By adding an additional 75' hose the station was able to successfully create the desired delay period.

INDUSTRY EXPERIENCE 2:
Another station injects the chemicals ~30' upstream of their carbon vessel.

INDUSTRY EXPERIENCE 3:
One station uses either of two injection points, either upstream of the first bed or between carbon beds. The decision process is based on influent characteristics and carbon use and performance history.

This pretreatment method is typically used in conjunction with top sluice, layered, activated carbon beds. At least one station has successfully employed the use of a second carbon bed to improve colloid isotope removal efficiencies. A top sluice carbon bed is desirable to preclude rapid increase in the differential pressure across the carbon media, increasing solid waste generation. The vessel's top sluice capabilities allow removal of the agglomerated solids on a periodic basis to control both general area dose rates and waste activity.

CAUTION: At one station the use of filters for agglomerated solids removal resulted in generation of high activity, low density solid waste. This resulted in a Class C waste product. That plant modified the chemical injection point to the filter effluent and carbon bed influent.

Several methods of polyelectrolyte addition to influent LRW have been successfully used to remove colloidal cobalt. Historically, fluctuations in LRW stream characteristics between process batches made identification of dosage and interface time difficult to determine. Advances in test, injection, and mixing equipment have improved the consistency of this technique's success.

At least one supplier offers a semiautomatic polymer injection configuration that constantly monitors the feed stream and adjusts polymer injection to a very precise level. The polymer is mixed with a proprietary substance to varying concentrations according to the particular waste stream. This process bonds the coagulant with the colloids to create larger particles, which is enough to remove over 90% of the total activity on the initial vessel or filter housing.

Bench scale column testing can be used to determine the optimal quantity of polyelectrolyte addition. One specific tool that has proven to be valuable to testing is a laboratory series particle charge detector (PCD). The PCD is used to measure streaming current and to determine if a solution is cationic or anionic. During testing, the LRW sample is typically titrated with cationic polymer until a streaming current of zero (0 mV) is reached. At this point the colloidal materials present in the waste stream have been destabilized.

Figure 5-1
Sample Particle Charge Detector

INDUSTRY EXPERIENCE: Using this process technology and technique, one plant was able to increase throughput from 2,000 gallons per ft^3 to 33,000 gallons per ft^3 of media consumed. The pertinent DF was also significantly improved.

> **INDUSTRY EXPERIENCE**: The impact of influent waste stream characteristics has impacted the success of this approach. At least one plant modified its reactor coolant chemistry to a modified lithium regime and experienced copolymer performance challenges. The causal factor(s) is not clear.

5.4.1.6 Hydrazine

Hydrazine represents an additional option for controlling colloidal iron species. Similar to other chemical additives, controlling the dosage, injection point, and reaction time are critical to successful implementation of this technique.

> **CAUTION:** At several stations hydrazine has been inadvertently introduced into the LRW system from draining steam generators and closed cooling system in relatively high concentrations. That waste stream negatively impacted the performance of processing media.

> **INDUSTRY EXPERIENCE 1**: During outages, one station maintains hydrazine concentrations of at least 2 ppm in waste collection tanks to control colloidal iron species that would otherwise result in transport of Co-58 through the entire system; that hydrazine also appears to eliminate the anaerobic bacteria.
>
> **INDUSTRY EXPERIENCE 2**: At least one station has had membrane performance challenged by residual hydrazine in influent waste. The resultant ammonia allows cobalt to pass through the membrane, increasing effluent activity.
>
> **INDUSTRY EXPERIENCE 3**: One station recirculated collection tanks to consume the hydrazine through oxygenation prior to processing.

5.4.1.7 Phase Separation

Copolymer, flocculant, or precoat media addition can also be used for improving particulate settling. Minimum or non precoat filters results in a reduction in solids (particularly iron oxide) settling efficiency. The particulate is then transported via the decant liquid to the LRW system, and severely challenges the process media. Chemically enhanced phase separation evolutions can improve solids separation and settling, which minimizes the impact of decant liquid on LRW processing media. Settling efficiency is impacted by several factors including:

- physical dimensions (height) of the separator vessel
- terminal settling velocity (particle size, particle density, liquid density, liquid viscosity)
- the treatment option employed

- settling time

It is critical that during settling periods, the vessel remain completely isolated to prevent agitation of the solid and liquid phases.

INDUSTRY EXPERIENCE: A two unit site's condensate polishing system was retro-fitted with pleated non-precoat filters upstream of the existing deep bed polishing ion exchangers. This resulted in a significant reduction in the solids challenge to ion exchange media and eliminated the need for URC. However, the filter backwash presented a severe challenge to the LRW system.

The contents of the filter backwash receiving tanks are transferred to condensate phase separators. After settling, the upper (liquid) portion of the phase separator is decanted to the LRW collection tank. The lower portion is allowed to accumulate solids until it is economical to process the solids into a HIC for disposal. The smaller iron oxide particles, no longer combined with spent media, were not settling in the phase separators. This heavy loading of small particles was severely challenging the LRW carbon and cartridge filters, and ultimately HIC dewatering laterals.

Initially, the LRW system was producing recycle quality water, but resin usage due to the new solids challenge was ~25% higher. Chemistry samples for jar testing were taken from the discharge side of the phase separator sludge pumps and decant samples. Test resin columns using activated carbon and ion exchange media were used to evaluate the effects of chemical additives.

The most consistent results were obtained using a commercially available polymer with NaOH addition for pH control. Polymer and caustic, followed by a demineralized water rinse, were pumped into the phase separator. The LRW system media throughput improved following this chemical pretreatment enhancement.

5.4.1.8 Ultraviolet Bacteria Control

UV light treatment is an extremely rapid physical process that causes a molecular rearrangement of the genetic material (DNA), of the microorganism. This blocks the microorganism's ability to replicate itself, and consequently its ability to breed colonies. Because of individual cell make-up, different microorganisms require different levels of UV energy for their destruction. The desired destruction energy level is referred to as dosage. Dosage is the product of Intensity and Time as shown below and is sometimes referred to as fluence.

Dosage= millijoules/(sec)(cm2) X time

= mJ/cm^2

Two wavelengths are employed, 185 nm (TOC destruction) and 254 nm (biological destruction). Typically ion exchange is required for TOC removal applications, and filtration is required for biological carcass capture. This technology is typically used in conjunction with ozone or peroxide addition.

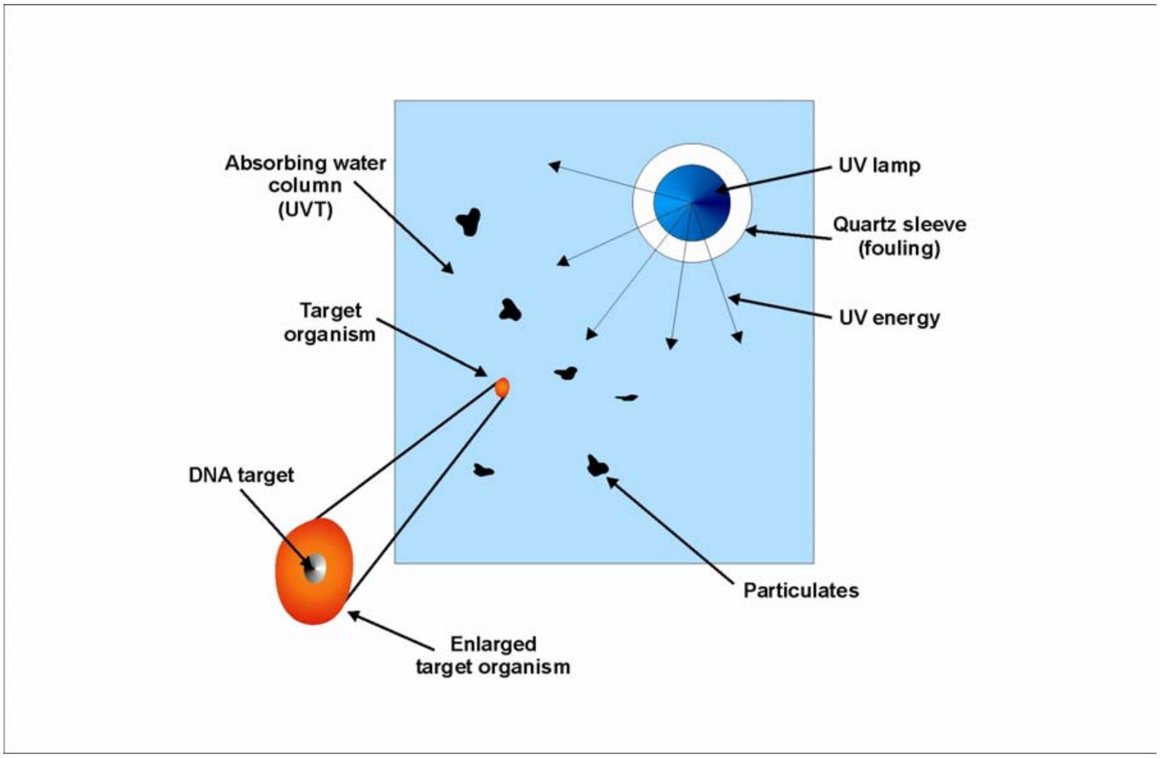

Figure 5-2
UV Treatment Overview
Source: Environmental Analytical Systems

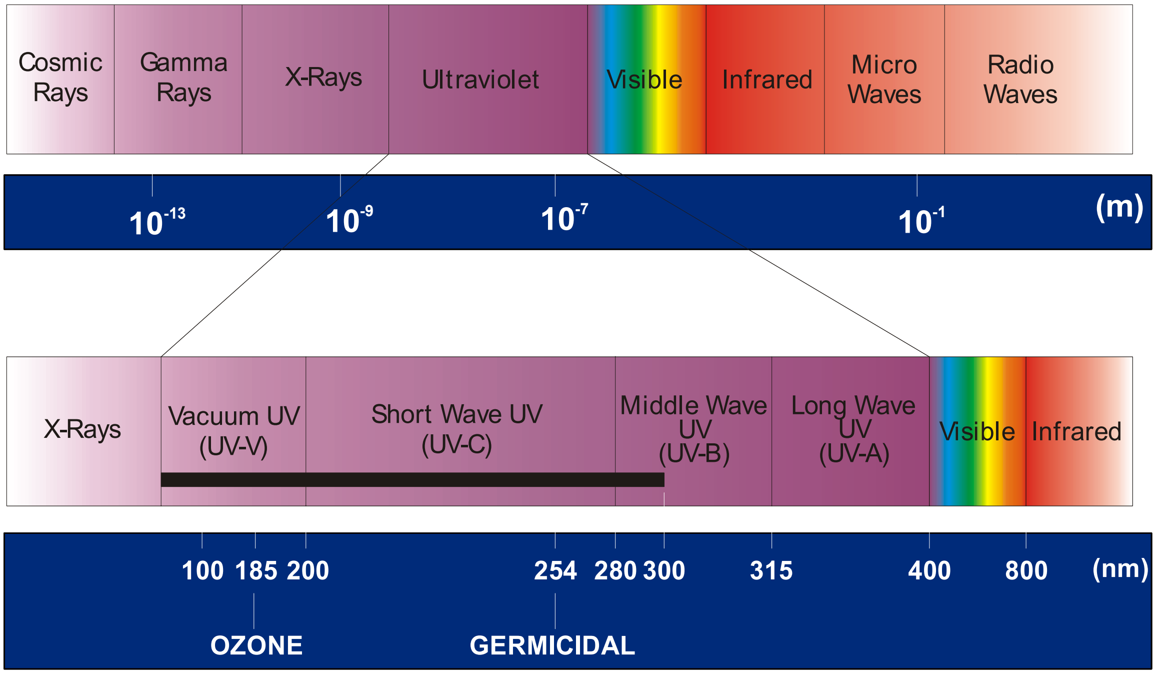

Figure 5-3
UV light spectrum effectiveness for TOC and biological destruction (http://www.enviro-analytical.com)

5.4.1.9 Chemical Addition Bacteria Control

Ozone

> **<u>CAUTION</u>**: Ozone technology requires an industrial safety review and process controls. Ventilation is typically required.

Ozone is a molecule of three oxygen atoms bound together (O_3). It is unstable and highly reactive. It is fast acting and produces few undesirable by-products. Used in combination with other physical, chemical or biological processes, ozone injection has the potential to treat complex waste streams due to its strong oxidative nature. It can be used to oxidize iron and manganese, and increase suspended particle size to help filtration. In combination with medium pressure UV, ozone oxidizes TOC and organics efficiently

The basic elements of an ozone system include ozone generation, feed gas preparation, ozone contacting, and ozone off-gas destruction components. For the low volumes and flow rates associated with LRW processing applications, those elements are typically incorporated into a single small unit. Additionally, for plants that recycle liquid for reuse in reactor systems, demonstration of 100% consummation of the ozone prior to liquid reuse may be required. A downstream activated carbon bed has proven to be effective for eliminating residual ozone from the waste stream.

INDUSTRY EXPERIENCE: Ozone generators have been used to eliminate organics that can irreversibly foul membranes, challenge other processing media, and result in methane gas generation in the resulting waste product. It has been successfully deployed at several stations.

5.4.1.10 Hydrogen Peroxide

INDUSTRY EXPERIENCE: At least one station adds hydrogen peroxide to their low quality, low activity waste collection tanks prior to processing to maintain at least 2 ppm during processing. This eliminates the anaerobic bacteria, which reduces the biological load on filters.

During outages, at least 2 ppm of hydrazine is maintained (versus peroxide), in the collection tank to control colloidal iron species that would otherwise result in transport of Co-58 through the entire system; that hydrazine also appears to eliminate the anaerobic bacteria.

CAUTION 1: Stations that recycle this waste stream should evaluate and be able to demonstrate that the H_2O_2 is exhausted prior to reuse.

CAUTION 2: H_2O_2 in sufficient concentrations can immediately and irreversibly foul ion exchange resin.

5.4.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

CAUTION: The station should carefully review updated final safety analysis reports (UFSAR), Licensing documents and release permits prior to using chemical additives to ensure system material compatibility and regulatory compliance. The use of a 10CFR50.59 and chemical control/industrial safety evaluation may be required or prudent to document procedural and regulatory compliance.

1. Bench scale (pilot) testing should be performed for most chemical pretreatments to determine the application benefits, limitations, and potentially negative issues.

2. For insoluble species removal, obtain filter media samples from the plant system filter supplier. The use of that media for benchtop filtration or ion exchange analyses will optimize the testing accuracy.

3. At a minimum include the following chemical use and control aspects when evaluating any chemical application:
   - Industrial safety evaluation related to chemical use, handling, storage and disposal. This may be accomplished in concert with the process 10CFR50.59 safety evaluation. This is typically required and controlled by the station chemical/hazardous material control program.
   - Procedural controls
   - Training requirements
   - Chemical control program guidance and restrictions
   - Typical LRW stream characteristics
   - Perturbations to LRW stream characteristics
   - Impact on other chemistry parameters
   - pH swings, conductivity, turbidity, foaming
   - Addition methods
   - Mixing
   - Particulate (iron oxide, solids) settling rate in phase separators/settling tanks.
   - Effluent liquid chemical purity specifications
   - Staff and other resource impact
     - Addition
     - Analytical
     - Resultant liquid waste processing
     - Resultant solid waste processing and disposition

4. Evaluate the processing system(s) and component(s) that will be impacted the by the chemical addition. As part of that evaluation consider:
   - Process Control Program
   - Packaged waste gas generation
   - Packaged waste agglomeration resulting in inability to transfer (e.g., for off site VR)
   - Off-site VR processing restrictions
   - Final disposal

- Carbon filtration performance
- Cation resin performance
- Activity buildup on the media
- General area dose rates adjacent to processing components and waste containers
- Media replacement and disposal costs.
- Solids settling during in-plant sluicing or transfer
- Waste packaging type
- Dewatering - ability and internals design
- Waste disposal options and limitations based on activity, dose rate, and chemical concentrations
- Impact of the added chemicals on media performance (e.g., premature depletion, sloughing, inadvertent regeneration, etc.)

5. The chemical injection point is critical to the success or failure of the liquid waste processing system.
   - Consider the residence time/contact time of the chemical injection point.
   - Determine the delay time that is required between the injection point and the process media for adequate mixing and reaction. The specific value is calculated using time, influent piping and hose length, system flow rate, and manufacturer recommendations.
   - Consider using a delay coil using the flexible hoses that are used to interconnect mobile/portable processing media vessels.
   - Consult with the equipment and/or chemical supplier or other expert guidance to ensure that design consideration is optimized.

6. Chemicals can be added using several techniques including:
   - An automated analysis and injection system- preferred.
   - A metering pump with an injection rate that is manually set and adjustable based on bench testing and effluent results - preferred.
   - Batch addition to tanks, sumps, etc.- less desirable method for solids agglomeration. This may result in the formation of sludge in tanks or sumps due to particulate settling.

NOTE: Periodically, a metering pump’s stroke should be evaluated relative to current influent characteristics. Optimally, the station should develop a proceduralized protocol for this process.

INDUSTRY EXPERIENCE 1:
Several stations have used flexible tubing connected to taps on the suction side of tank recirculation pumps drawing from a mixing/addition container. The injection rate is controlled using a manual throttle valve that is set based on bench testing, historical experience, or effluent results. This method results in widely varying results and can introduce air to the pump suction resulting in cavitation and possibly pump damage. Therefore, this technique is specifically NOT recommended.

INDUSTRY EXPERIENCE 2: One station successfully resolved resin sluice water problems by modifying the chemical injection rate+.

7. Carefully monitor system performance to preclude severe chemical changes such as pH swings that can result in acid wash, sloughing, less than desirable effluent, or premature media depletion.

8. Copolymer addition should include the following considerations:

   – Inject the copolymer into the subject LRW stream upstream of the carbon filter vessel, versus directly into the influent waste collection tank.

   – The use of two injection points, either upstream of the first bed or between carbon beds. The decision process should be based on influent characteristics and carbon use and performance history.

   – Evaluate adding second charcoal bed for adsorption of colloidal activity. A graded carbon layering strategy is recommended for that vessel. One example would be a coarse mesh underlay, followed by medium mesh and capped with a coarse mesh overlay. Refer to Carbon processing section of this document for additional detail.

   – A top sluice carbon bed is desirable to preclude rapid increase in the differential pressure across the carbon media, increasing solid waste generation.

CAUTION: A high dP is typically indicative of a high solids loading on the carbon media. If the dP is allowed to increase substantially, top sweeping the vessel and removing the desired volume of captured solids (media and the solids “bathtub ring” inside vessel) may prove to be difficult.

   – The vessel’s top sluice capabilities allow removal of the agglomerated solids on a periodic basis to control both general area dose rates and waste activity.

9. Ultraviolet bioassay testing and operation can be performed using the following general guidance:

   – Test water first (UVT as well as other recommended parameters).

     o A microorganism with know sensitivity to UV light is selected. It is normally non-pathogenic and easy to grow in the lab.

    - Apply exact UV doses to the microorganism to create a calibration curve of UV energy vs. log kill.
    - Prepare a UV system to simulate worst case conditions of the lamps and water.
    - Feed the calibrated microorganisms through the reactor chamber at different flow rates and measure the numbers in the influent and the effluent to get the log kill.
    - Using the calibration curve create a curve of flow per lamp vs. UV dose.
  - UV can only be effective if it is absorbed by the target.
    - Suspended solids shield microorganisms.
    - UV treatment is most effective following filtration.
  - UV absorption in water is almost entirely caused by dissolved substances. Certain inorganic substances such as iron and manganese absorb UV.
  - Pretreatment is required to meet recommended UV chamber influent quality requirements of:
    - Iron: < 0.3 ppm (0.3 mg/L)
    - Manganese: < 0.05 ppm (0.05 mg/L)
    - Turbidity: < 1 NTU
    - Hardness: < 7 gpg (120 mg/L)
  - Hardness causes the formation of scale on the quartz sleeve surface and prevents design UV transmission.
  - Iron can stain the quartz sleeve impeding UV transmission
  - Lamp operating temperature impacts lamp intensity, with the optimum temperature being 40°C. Quartz sleeves will minimize temperature fluctuations.
  - Flow rate design should take into account energy level fluctuations.
  - Consider installing a sample port, unit by-pass, drains and a flow restrictor.
  - Commercially available UV lights now come with an intensity meter, which are useful for diagnostic purposes.

10. Ozone treatment should include the following general guidance:
  - Industrial safety—Ozone is potentially hazardous and ventilation may be required.
  - Test water to identify target constituents.
  - Ozone generators may require an external oxygen source.
  - Ozone is highly reactive and should be treated and maintained accordingly.
  - For recycle operations, verify that the ozone is consumed prior to recycling liquid to reactor systems.

5.4.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. NP-5786, "Pretreatments and Selective Materials for Improved Processing of PWR Liquid Radioactive Waste", 1988.

3. EPRI. "Radioactive Colloid Removal by Optimizing Chemical Parameters, Phase II – Media Testing", 2001.

4. EPRI. NP-5099, "In-plant Testing of Radwaste Ion Exchange Materials", 1987.

5. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

5.5 Program Element: Single-Use Cartridge and Bag Filters

5.5.1 Program Impact

The primary function of a filtration device is to reduce or eliminate undesirable insoluble contaminants from fluids prior to encountering sensitive components. These contaminants, when allowed to flow freely in a fluid system, deplete downstream processing media, and can cause wear, malfunction, and often failure of expensive components. Filtration is deployed as a stand alone effort, or to provide protection to follow-on ion exchange media or membranes. It is also used to capture processing media fines that pass through media vessel retention elements.

5.5.1.1 Media Options

Cartridge filters are typically manufactured as either wound/extruded or pleated elements. Bag filters are bags manufactured from woven materials and are used in a limited number of applications for gross particle capture. Several manufacturers produce deep filtration media in a graded density melt blown polypropylene bag design, but its use in US nuclear applications is not well documented. Typical materials of construction include:

- Cellulose basis, resin impregnation.
- Microfibre glass.

> **CAUTION:** Glass fiber filters will catastrophically fail at 180 degrees F and will not meet most NSSS 250 degree F specifications.

- Cloth fiber.
- Thermoplastic plastics.
  - $(CH_2CH_2)x$.
  - polypropylene, polyester and polysulphone.
  - resistant to chemicals and moisture.
- Metal or polymer based support structures and end caps.
- MYCELX filters to be included.
- Other man-made products.

Recent advances in media manufacturing technologies have made it feasible to produce filters that are impregnated with ion exchange media or polymeric compounds for organic capture. These options combine the standard unit processes of filtration and process enhancements within a single filter. For ion exchange applications, filtration is controlled by inner and outer wraps of flat media with specific micron ratings. The ion exchange components are proprietary media made from inorganic and organic components. The media are chosen for selective removal of specific radionuclides from waste stream. The ion exchange media provide some secondary filtration capability as well. Because of the high cost, they are employed as polishing filters. The elements are engineered to provide a final polishing function for the purpose of removing trace amounts of radionuclide contaminates that remain in the liquid radwaste stream. The elements will remove both suspended (filterable) and dissolved (ion exchangeable) contaminants (radionuclides) from a waste stream. The elements are both compactable and suitable for thermal destruction.

The polymeric compound filters used for organic capture involve infusion of those compounds into a variety of substrates. As the hydrocarbons come into contact with the material, they are dissolved and bond into the material, preventing re-dispersion.

INDUSTRY EXPERIENCE 1: One station has used impregnated filters targeting Cobalt removal for over one year. The throughput for this application was 225,000 gallons per element. In addition to removal of cobalt, these filters also reduced effluent antimony. The optimal filter performance occurred with relatively consistent feed contaminant levels.

INDUSTRY EXPERIENCE 2: Another station has used filters targeting cesium as polishing filters. Used on the effluent of a liquid processing system, the filters were effective at selectively removing cesium, and were able to process over 275,000 gallons of water. The filters were also effective in higher cesium concentrations, and could be used for special waste streams that are high in cesium and high conductivity. To ensure the filter use remains cost effective, they require upstream protection against ion exchange site fouling with other insoluble species. This can be accomplished with an up stream filter or carbon bed to prevent the filters from exhausting prematurely on dP.

CAUTION: The station should carefully review updated final safety analysis reports (UFSAR), Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

5.5.1.2 Selection and Loading Logic

Single-use cartridge and bag elements come in a variety of sizes, materials, and micron ratings. Developing a set of selection criteria for a single use disposable filter requires knowledge of both process application and available alternatives. When selecting a filter, the base analysis outlined in Section 6.1 should be used to thoroughly research the intended function of the filter and the “typical” characteristics of the liquid waste to be processed.

Several additional considerations are specific to filtration processing.

5.5.1.3 Micron rating versus application

Filters are segregated into two removal categories, nominal and absolute.

- Nominal Rating: the filter that will remove up to 98% of the rated particulate size.
- Absolute Rating: the filter will remove 99.9% of particles of the specified size (in microns) or larger.

There general classifications for filtration ratings are illustrated in Figure 5-4.

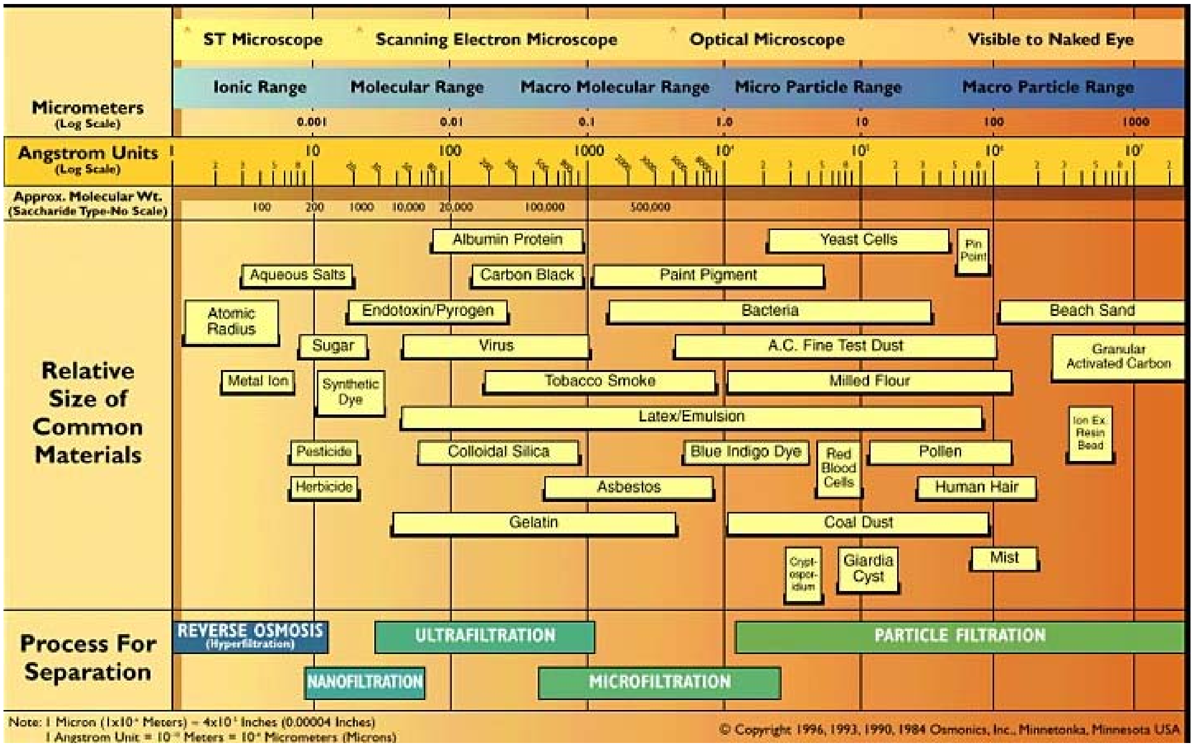

Figure 5-4
Particle Size Chart (http://www.osmonics.com)

Micron rating terminology can be very confusing. There are nominal ratings, absolute ratings and beta efficiency ratings. In general, absolute ratings are gaining preference. A media rated at X microns absolute usually refers to a media that removes 99.9% of all particles of size X and above. These ratings are dependent on flow rate, type of challenge particles and the method of counting particles upstream and downstream of the filter media. There are also absolute ratings “at size”, which means 99.9% removal of particles at X microns to X+1 microns. This is a more stringent rating, because the removal efficiency cannot be “enhanced” by removal of large quantities of particles much larger than X.

A sub-micron filter used in a process and release scenario can, dependent on the waste stream, provide little additional benefit at a substantially increased cost. Similarly, a small micron filter as the lead component in a demineralizer train or with an evaporator used for processing low quality floor drain wastes would foul frequently with minimal resultant benefit.

INDUSTRY EXPERIENCE: Contrary to the current industry move to absolute filtration, at least one station has reverted to a 0.5 micron nominal rated filter. Their plant processing evaluation indicated that their recent absolute rated strategy did not produce consistent or cost effective results.

There are several filter performance test standards. A single pass particle challenge test (ASTM F-795) with optical particle counters (ASTM F-661) is perhaps the best test to specify as it simulates full scale operation. It is important to require a high flux rate (5.6 GPM/ft^2) for the test. Most filter manufactures literature report efficiency at low flux rates (e.g., 0.5 GPM/ft^2). One supplier learned that their filters below 3 micron (based on low flow performance) could not pass the high flow test.

The choice of particle challenge media (AC test dust, AC fine test dust or iron oxide), the concentration of those particles in the test feed stream and the flow rate must all be specified. Although there are considerable data on AC fine test dust, iron oxide is probably closer to material that must be filtered in RCS, boron recycle and equipment drain systems. Neither AC fine test dust nor iron oxide can be used for submicron filter performance tests because of an insufficient number of submicron particles. A paint pigment, Harcross BK-5099, has been used by AECL and PG&E successfully to test submicron filter media.

5.5.1.4 Anticipated waste stream characteristics and fluctuations

Understanding the chemical and radiological characteristics of the liquid to be processed is critical to process success. Off-standard inputs to the system can seriously challenge the performance of the filter. A large influx of decontamination, housekeeping liquid waste, or auxiliary cooling water (river, lake, ocean) could rapidly blind a bag or cartridge filter.

Similarly, the impact associated with other process media application requires consideration. Several stations have reported that the use of macroporous resin in RCS cleanup and letdown purification system vessels has reduced the particulate challenge to waste system filters. This in turn reduces the frequency of changeout and related exposure, cost, and generated waste volume.

5.5.1.5 Cost versus application

The costs associated with filtration are directly related to specifications provided by the site and the filter manufacturer. The cost can vary dramatically with minor changes in filtration specifications.

5.5.1.6 Material versus VR and disposal options

VR and disposal options and costs are largely based on filter material and activity. The materials of construction should be analyzed to define volume reduction and packaging options. For example, non metal, poly based filters can be volume reduced using incineration or pyrolysis. Filters with metal internal and/or external support structures may be suitable for shearing or shredding technology or off-site supercompaction. It is important to note that depending on the nature of the solids collected on any filter element, organic matter may result in biogassing in packaged waste containers or may impact thermal VR process efficiency.

INDUSTRY EXPERIENCE: One station aggressively pursues the use of filters that can be thermally destroyed.

1) Incinerable industrial style cartridges are used in condensate polisher discharge, boric acid evaporator distillate, boron injection and contracted steam generator sludge lancing vessels.
2) The station also required their steam generator chemical cleaning contactor to use cotton wound filters with high temperature resistant poly cores.
3) The station recently gained approval to use all plastic incinerable filters in non-Q "nuclear" vessels. These drop-in filters do not require any insert in the filter vessel.

NOTE: The current pyrolytic reactor receiving drop tube can only accommodate elements of 6" diameter or less.

These spent filters are all suitable for thermal destruction, resulting in minimal waste residue in a form conducive to both direct disposal and long term on-site storage.

Filters can be manufactured without metal components employing <u>either</u> rigid poly based supports, <u>or</u> using reusable support sleeves that are retained as an integral part of the filter housing. These options increase the VR options to include incineration and/or pyrolysis. Similar to the majority of cartridge and bag filters this type of cartridge can be installed or removed by hand or by using a filter removal and insertion tool, and their VR options are governed by dose rate and activity constituents.

Filters can also be packaged for overfill. This operation is typically performed by off site vendors, filling filter void spaces with other waste streams; the disposed volume is then calculated based on the filter media volume resulting in a net disposed volume reduction.

<u>CAUTION</u>: This operation typically requires commingling wastes from other generators. This produces a final waste stream that is not acceptable for return to site for storage due to site radioactive material license restrictions.

5.5.1.7 Flux and square feet of media

Cartridge and bag filters are typically associated with conventional and micro-filtration targeting capture of particles 0.1 μm and greater. At least one vendor is in the process of developing 0.05 μm media. The material and construction of the porous filter medium determines the type or category of filtration process. In general, if the size of the filter surface area is increased and the volumetric flux is constant; higher flow rates are possible, the filter will last longer, and the dirt and activity holding capacity also increases.

Cartridge filters can be designed for depth or surface filtration. Depth filters (wound or asymmetric membrane cartridges) capture contaminants through the total thickness of the medium and selectively remove particles in graduated densities for optimal filtration. Progressive removal of particles from surface to core provides true depth filtration and a large contaminant holding capacity. Surface filters (pleated) capture particles at the surface of the media. The pleated material provides additional surface area for high dirt and activity loading capacities and extended life while maintaining minimal pressure drop.

Bag filters are typically surface filters used to capture large particles and foreign objects. Bag filter housings are normally designed for an inside-to-out flow pattern, capturing the contaminants on the internal surface of the element.

The rate at which a filter will be fouled is directly influenced by the filter flux (process flow rate per area of filter media-gpm/ft^2), and the waste stream characteristics. This knowledge is critical when developing a filter selection specification to ensure filter performance is optimized. Generally, a greater available surface area will result in higher solids loading and longer the filter life.

5.5.1.8 Operation

Effective particulate removal combined with extended, consistent filter run lengths are typically the desired attributes of a successful filtration program. Extended filter life can be an indicator of desirable plant collection system health and positive influent water quality controls. Reducing the influent challenge to filter media can result in improved effluent quality, increased processing rates, reduced filter media waste, and reductions in associated labor and disposal costs.

CAUTION 1: Conversely, extended filter life may be representative of inadequate waste stream particle size and distribution characterization; micron ratings that are larger than required will result in poor removal efficiency and extended runs.

CAUTION 2: Extended filter life can also be indicative of improper filter seating/sealing. Particulates will bypass the filter taking the path of least resistance.

INDUSTRY EXPERIENCE: One station has developed a go/no-go filter seating test gauge. New filters are evaluated using this simple device for proper sealing prior to installation in a radioactive system.

The majority of filters are in service until predetermined differential pressures (dP) or dose levels are attained. The waste stream characteristics impact both of these factors, again stressing the importance of an accurate characterization. Differential pressure is indicated by installed instrumentation and the maximum dP is typically established by the manufacturer to preclude a decline in filter performance, membrane failure, or cartridge collapse.

The filter dP directly impacts the flux through the filter modifying its ability to effectively filter particles at the design flow rate, as well as potentially impacting filter feed pump operation. Figure 5-5 shows a typical filtration dP curve indicating the filtration characteristics at varying dPs and volumetric throughputs.

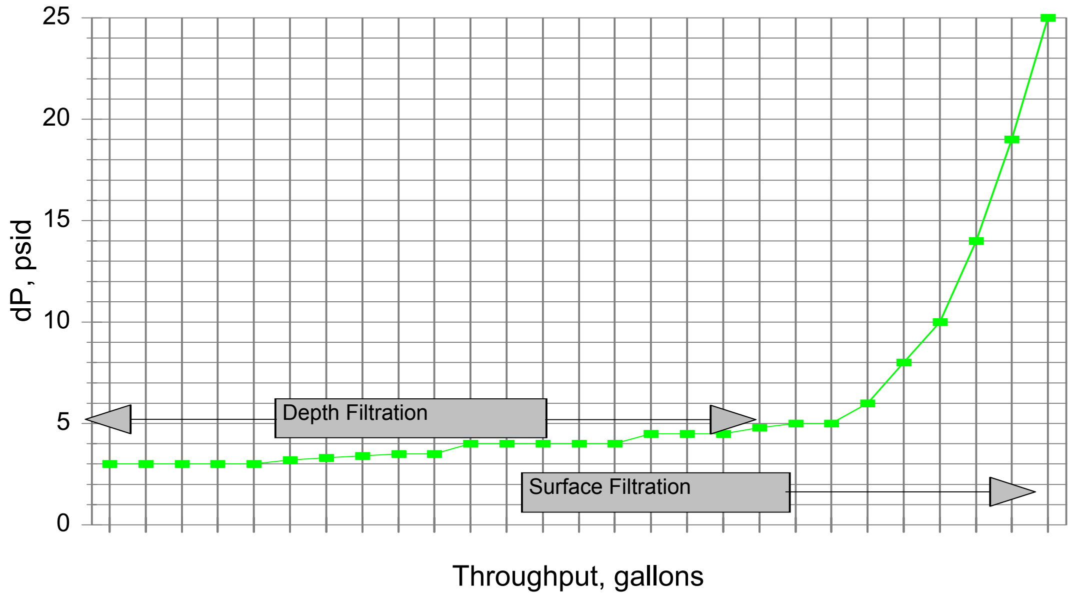

Figure 5-5
Typical dP versus Throughput Curve

During outage periods, the potential exists for higher volumes of liquid waste along with a significant increase in particulate impurities. Low quality liquid wastes will result in more rapid filter fouling, increasing process related costs and waste disposal volumes. These factors negatively impact processing operations by challenging holding tank capacity, release tank capacity, and filter performance. Many stations successfully use portable filters both as a primary method or pre-processing of low quality LRW. The applications include reactor cavity, cavity drain down and sump/tank cleaning evolutions.

Radiation instrumentation is used to monitor filter and general area dose rates during operation. This option is particularly valuable for applications that involve the potential for rapid and/or high levels of activity buildup on the filter media. The type and frequency of monitoring is based on operating experience and liquid stream activity projections. Remote wireless, hard wired, and electronic dosimetry have all proven to be effective monitoring concepts. Filter dose rates can be readily converted to estimated activity using commercially available dose-to-curie software and filter vessel geometries. The general area dose rates provide information for assessing and establishing radiological controls.

5.5.1.9 Changeout

Activity limitations are frequently determined by site radiological controls or radwaste organizations based on the measured dose rate adjacent to the filter housing. When determining change out criteria for filters, it is important to consider more than the filter dose rate relative to ALARA and the dP based on manufacturers recommendations. As the activity of a filter increases, the associated packaging, shipping and disposal costs increase significantly. In many cases, the procurement and waste VR cost savings associated with increased throughput are off-set by activity and waste class cost increases. The extreme case is generation of greater than Class C waste for which no “normal” disposal options currently exist.

The majority of sites assign an exposure cost value per person-Rem. This cost should also be considered when evaluating changeout criteria.

Filter changeout strategies should include a detailed ALARA plan. Remote monitoring, tooling for filter removal (and installation), filter transfer and packaging can result in significant reductions in personnel exposure. Several stations use remote, shielded changeout apparatus. These devices mate to the filter assembly and the filter is remotely grappled and pulled into the shielded transfer housing. That housing is used to transport the filter to the waste container where the filter is remotely removed from the housing and dropped into the container. It is recognized that not all stations have the structural access or lifting capacity required for this type of technology. However, variations of this approach can still employ partially remote tooling and transfers and reduce the overall process exposure.

Additionally, remote dose rate, exposure and audio/visual (a/v) equipment can result in improved process efficiency and reduced exposure. A/V recordings are useful for post job evaluation to identify potential process improvements and for time motion studies for dose estimating and personnel dosimetry placement.

5.5.1.10 Waste Packaging, Volume Reduction, and Disposal

As discussed previously, the packaging and disposal options are primarily controlled by the filter’s activity and VR processes. Additionally, these program elements are impacted by:

- Plant structural and space constraints.
- Waste concentration averaging.
- Available plant VR equipment.
- Disposal availability (long and short term).
- Disposal pricing structure.
- Available vendor services.

The materials of construction should be analyzed to define volume reduction and packaging options. For example, non metal, poly based filters can be volume reduced using incineration or pyrolysis. Filters with metal internal and/or external support structures may be suitable for compaction, shearing, or shredding technology or off-site supercompaction. Shearing and shredding is typically more labor intensive than direct packaging, but it will result in significant VR values.

Assessing the cost effectiveness of any filter volume reduction technique requires careful consideration of the following:

- Total activity per waste container volume
- Waste container selection
- Transportation cask type and fees
- Disposal costs
- Filter handling, packaging, and shipping labor

At least one VR processor provides options for overfilling filter waste with residue from their other thermal VR process. This option results in an as disposed "VR" by filling void spaces in waste containers.

> **CAUTION:** If filter waste is going to be returned to the site for on-site storage, commingling wastes from other sites (overfill) is NOT recommended. This would result in receipt of radioactive waste streams for which a utility is not licensed to receive. Also, VR options for stored filter waste may become available in the future and separating filters from the overfill material may be inefficient or impossible.

5.5.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

5.5.2.1 Selection and Loading Logic

1. Characterize known, recurring waste streams and review historical data for off-standard media challenges.
   - Chemical
   - Activity
   - Particle size and distribution
2. Evaluating all characterization and process related data and goals that impact filter selection and change-out criteria. Include the following in the analysis:
   - Particle size and distribution analysis – include an evaluation of oxygenation impact on particle ionic state and size
   - Target particulate species – what is the desired filter effluent goal?

- Process flow rate
- Actual benefit derived – evaluate each application individually (e.g., using reduced micron filtration – lower micron ratings in all applications may not be practical or cost effective).
- Costs associated with personnel exposure, filter procurement, change-out and disposal.
- Exposure associated with reduced source term, filter change-out, packaging, and disposal.
- Impact of particulates on equipment and/or other processing media such as resin.

3. Evaluate the use of impregnated cartridge filters for specific nuclide removal.
   - Consider their use as a final component in the configuration acting solely as a polisher.
   - Carefully assess the influent waste stream consistency.
   - Consider the impact of other nuclides that may compete with the target nuclide for ion exchange sites.
   - Include the additional cost and upstream anti-fouling protection requirements associated with using this technology.
4. Establish non metal, poly-based filtration goals for all applications. The goal may not be 100% attainable, but would force evaluation of this technology, and if applicable, will result in increased VR options.
   - This may also result in reduced per element costs as compared to filters with metal components.
   - Evaluate spent media handling tools, transfer shields, and temporary storage to validate compatibility or to identify necessary modifications to those processes.
5. Formalize procedures, schedules and planning for filter selection based on known plant evolutions. Proceduralize plant mode filtration guidance to ensure filtration remains cost effective and produces the optimal results. This approach is also valuable for other filtration options including cavity cleanup and draindown, and spent fuel pool purification.
6. Ensure that the filter micron rating is commensurate with the intended function. The waste stream characterization, processing system goals, and process flow rate should be used to select a micron rating for the desired performance..
   - In general, sub-micron filters as lead filters for waste processing is not recommended.
   - Absolute rated filters should be specified for all applications unless it is determined to be cost prohibitive. Nominal rated filters' performance will vary widely based on individual manufacturer specifications and testing criteria.
7. The implementation process for sub-micron filters should be a "stepped" approach, decreasing the micron rating over a period of time to permit system particle size reduction with minimal filter waste generation.
8. Anticipated waste stream characteristic fluctuations should be incorporated into the filter specification as appropriate. Known fluctuations or expected perturbations based on planned

and projected plant evolutions should be analyzed for impact on filter performance. Consideration should be given to specifying a multiple range of filter element ratings for a single housing to address this issue.

9. Evaluate the impact associated with other process media applications. Macroporous resin in RCS cleanup and letdown purification system vessels may reduce the particulate challenge to waste system filters. This may impact the optimal micron rating and may impact the frequency of changeout and related exposure, cost, and generated waste volume.

10. Following process stream characterization, develop separate detailed procurement specifications for each filter application. Avoid the use of a single generic filter design for different waste streams for the sole purpose of streamlining the procurement and on-site warehousing process.

11. Evaluate the filter procurement and disposal cost against application in the system. Filtration of a liquid to the maximum extent possible is not always cost effective and may not result in a justifiable derived benefit. Use "off the shelf" filters whenever possible to minimize the cost increase associated with custom designs and manufacture. The increased cost associated with absolute or sub-micron filters is difficult to justify for process and release applications, unless particulate activity is a major portion of the nuclides released.

> **INDUSTRY EXPERIENCE:** Recently, a few stations have successfully utilized sub-micron filtration on the effluent of their processing system as a polishing process to reduce effluent activity. This cost should be analyzed in conjunction with applicable processing program goals.

12. Incorporate VR and disposal options in the filter selection evaluation.

13. Target minimum filter flux in the selection process. The filter surface area should be maximized by using longer or larger filter elements, more filter elements, or filters with more surface area, such as pleated filters. Pleated filters have approximately five times the available surface area as opposed to cord-wound filters.

14. Organic removal filters (polymeric compound) are typically applied in a polishing configuration, removing residual hydrocarbons prior to recycle or release.

15. Ensure that as built filter dimensions are carefully defined PRIOR to filter specification finalization. Frequently plant drawings do not accurately reflect as built data.

5.5.2.2 Operation

1. Evaluate the component and manufacturers dP rating
   - Operate the filter to a value below the filter cartridge manufacturer's recommended maximum dP to preclude filter failure.
   - Vendor changeout dP recommendations can be intentionally low – work with vendors to assess higher dP limits for extended operation.

<u>CAUTION</u>: Exercise caution when operating in excess of baseline vendor recommendations. Element failure may result in an undesirable effluent product or dispersion of filter media into the effluent product. Either option may negatively impact downstream processing components or plant equipment.

2. Monitor the filter dP over the life of the filter.

3. Use remote monitoring to trend the filter dose rate. This information can be used to keep changeout exposure ALARA and waste classification estimating.

4. Anticipate fluctuations in influent quality and have pre-approved alternate filter types available for use as appropriate.

5. Reduce system flowrate and filter flux to the extent practical. This will increase filter efficiency and loading prior to reaching the dP endpoint.

6. Filter dP that is not increasing or increasing very slowly MAY be indicative of improper filter micron rating, and/or improper element sealing.
   - Evaluate seating surfaces and particle size and distribution testing results.

5.5.2.3 Changeout

1. Define specific changeout criteria. As part of that analysis, consider:
   - The impact of waste classification on filter operation.
   - Personnel exposure
   - **<u>In plant</u>** spent filter changeout, transport, volume reduction and packaging.
   - Costs - new filter, changeout and packaging labor, and disposal (including activity surcharges).

   Establish and proceduralize cost effective filter activity limits based on this analysis.

CAUTION: Ensure limits are restrictive enough to preclude generation of Greater Than Class C waste. Ensure defined limits do not increase the specific activity of nuclides such as carbon-14, nickel-63, or transuranics (TRU) to levels that result in Greater Than Class C waste (refer to regulations for guidance).

2. Perform an analysis to determine the filter activity as related to dose rate correlation using the waste stream 10CFR61 isotopic analysis results, filter and vessel construction, and shielding models. Historical data can enhance this process, providing actual media data. Based on that analysis define an operating limit related to the filter housing external surface dose rate.

3. Establish an ALARA spent filter handling process. This process may employ transfer bells, remote grips, tooling, remote radiation and AV monitoring and recording. Recent advances in these areas have resulted in significant dose reduction and reduced costs.
   – Minimize multiple handling of spent filters typically associated with storage adjacent to the filter housing, packaging preparation, dewatering and final transport for disposal.

> **INDUSTRY EXPERIENCE**: A/V recordings have proven to be useful for training and for post job evaluation. The information can be used to identify potential process improvements and for time motion studies for dose estimating and personnel dosimetry placement. It is also useful for pre-job briefings.

5.5.2.4 Waste Packaging, Volume Reduction, and Disposal

1. Perform a safety analysis (UFSAR and industrial)
2. Evaluate on and off-site VR options.
3. Review established target activity limits relative to filter dose rate, VR, and disposal. Where applicable, adjust limitations to maximize the use of VR techniques and minimize disposal costs.
4. Poly-based filters suitable for incineration or pyrolysis will result in substantially reduced volumes, increased disposal packaging efficiency, an increased waste density (possibly), and the potential for reduce disposal costs.
5. Evaluate filter choppers, shredders, and compaction for volume reducing elements not eligible for thermal destruction.
6. Analyze each waste packaging, VR, and disposal option to define the most cost effective or optimal long term strategy.

> **INDUSTRY EXPERIENCE**: Many stations have used the EPRI Waste Logic™ cost and performance programs to perform detailed, comprehensive feasibility analyses.

> **CAUTION:** Ensure changes to packaging strategies remain in compliance with the Process Control Program (PCP), and container C of C and procedures.

That analysis should include the following factors:

– The impact and availability of on off-site and on-site VR and disposal options – current, and future following on-site storage

– Waste classification

- Total activity per waste container volume
  - Specific activity of nuclides such as carbon-14, nickel-63, or transuranics (TRU) to levels that result in > Class C waste
- Waste container selection - material, size, weight
- Transportation cask type and fees
- VR costs
- VR equipment capital expenditures
- Disposal costs
- On-site storage costs
- Filter handling, packaging, and shipping labor
- Stabilization requirements
- Density impact
- VR and packaging efficiency
- Dose rate
- Filter handling, packaging, and shipping support equipment (e.g., dewatering, transfer shields, waste container shield, tooling) cost and adequacy
- Burial site or on-site storage specific criteria

CAUTION: Spent elements should be evaluated for the potential for gas generation and stored and packaged accordingly. Additionally, an industrial safety evaluation may be warranted

7. Analyze the site structural layout to ensure filter VR, packaging and transport preparation evolutions are optimized. As part of that evaluation consider alternate use of existing facilities, addition of simple, cost effective alterations, and removal of equipment “retired in place” for optimizing the use of alternate space.

5.5.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386-V3P2, “Radwaste Desk Reference: Volume 3, Parts 1 and 2”, May 1994.
2. EPRI. TR-105859, “Cost Effective Liquid Processing Programs”, 1995.
3. EPRI. Waste Logic™ software programs and user manuals.
4. EPRI. RS-107201, “Low Level Waste Characterization Guidelines”, 1997.
5. EPRI. TR-1009566 “Non-Metal Filter Study”, Palo Alto, CA: 2004.

5.6 Program Element: Membrane Systems

5.6.1 Program Impact

Membrane systems have been successfully deployed in a variety of LRW processing applications in both BWR and PWR stations. The systems are used for processing high and low conductivity waste streams for both recycle and release strategies. When properly designed and operated, their performance is comparable to, or better than, traditional evaporator/ crystallizer treatment technology.

Ultrafiltration (UF) and reverse osmosis (RO) based systems are used to separate impurities, and concentrate them in a reject solution. That reject is typically re-routed to the influent of the system for additional processing that increases the concentration of solids to a predetermined value. The final reject solution is then processed using thermal treatment, filtration separation, or ion exchange. For cost savings, several plants use partially depleted spent condensate media. The product water (permeate) is very high quality and typically results in effluent activity that is close to MDA values for recycle or release.

5.6.1.1 Influent Characterization

In-plant and other industry experience have consistently demonstrated that influent waste stream knowledge and pretreatment are ***critical*** elements to successfully implement this technology. Understanding the particulate, chemical, biological, and isotopic traits of the influent stream allows for the selection and design of membranes and process configurations with the highest success rate. The effects of off-standard influent can be devastating. The effects may result in fouling, irreversible organic fouling (especially attributable to influent lubricants), or cut or chemically deteriorated membrane materials that will require chemical cleaning or replacement.

> **INDUSTRY EXPERIENCE**: Several stations have experienced irreversible fouling of ultra filter and reverse osmosis membranes by biological contaminants. These are typically a result of rain or groundwater intrusion, service water draining, and residual influent stream oil. The membrane replacement and subsequent recovery process were both lengthy and very costly. Aggressive control of draining and in leakage is critical to membrane processing success.

A careful and accurate influent waste stream characterization is necessary prior to membrane selection and system design. Typical inputs, off-standard inputs, and surge volumes would need be identified and characterized. Based on that influent characterization, membrane influent pretreatments would need to be evaluated and selected.

INDUSTRY EXPERIENCE: At least one station has had membrane performance challenged by residual hydrazine in influent waste. The resultant ammonia allows cobalt to pass through the membrane, increasing effluent activity. One station recirculated collection tanks to consume the hydrazine through oxygenation prior to processing.

5.6.1.2 System Configuration and Membrane Selection

Configurations vary widely, but typically involve some combination of gross filtration (conventional or micro), a feed tank, pretreatment, carbon, UF and/or RO, ion exchangers, and a post filter or resin strainer. The specific functions also vary. The following are typical examples:

- Gross filtration: protect downstream components from particulate loading or mechanical damage and enhance the effectiveness of pretreatment technologies.
- Carbon vessel: to prevent any organics and oxidizing agents from reaching the membranes.
- Feed tank: provides suction head for the system pump(s) and provides holdup capacity for collecting and concentrating the UF and/or RO reject stream.
- Chemical Addition tank: Oxidizing chemicals can include calcium hypochlorite, sodium hypochlorite, ferric chloride, stannous chloride and ozone.
- UF: removes insoluble contaminates down to ~0.007µm. Provides protection for downstream RO and/or ion exchange beds.
- RO: semi permeable membrane removes ionic impurities through separation, generating a reject and permeate stream. Results in a high purity effluent product requiring minimal, if any, post treatment.
- Ion exchangers: cationic, anionic, or mixed bed applications provide polishing following UF and/or RO processing. Have been applied upstream of RO systems to protect RO membranes.
- Post filter or resin strainer: captures resin fines and other impurities, reducing the potential for impacting downstream tank water quality.

Utility experience with membrane processing has been varied and includes an array of spiral wound, hollow fiber, tubular and vibrating disc designs. The type of processing (UF or RO), micron porosity, and the membrane materials are all dependent on impurity type and concentration. The three types of membrane material currently available include cellulose acetate, polyamide, and polysulfone. Generally, polyamide membranes provide greater fouling resistance and high salt rejection in RO systems at half the operating pressure of cellulose acetate membranes. Polysulfone materials are used in UF applications because of their ability to pass salts through membrane pores.

The membrane material selected should be compatible with chemical cleaning processes (typically recommended by the manufacturer). However, in nuclear applications, the potential for creating a mixed waste during chemical cleaning exists and may require selection of alternate membranes or chemical cleaning agents. In addition, chemical cleaning agents can deteriorate the membranes. Ineffective waste stream pretreatment may increase chemical cleaning frequency and result in reduced membrane life.

Desired system process rates also affect the selection and design process. Historically, the majority of membranes operated better at higher pressures to increase the membrane flux (gpm/ft^2), but the flow rate per square foot of membrane is lower than that of conventional media. Therefore, in an effort to increase the process rate, system designs typically incorporate several elements in series within a single pressure module, with several modules configured for parallel operation. Advances in membrane technology have facilitated lower pressure system designs.

Membrane processing will require periodic membrane replacement. For single train membrane systems, **processing may be required to be secured completely**. Evaluate the membrane replacement duration and process options such as processing using alternate process components including membrane support filtration and demineralization or alternate systems. Additionally, waste handling, VR, and disposal options need to be considered to ensure the membrane type and configuration optimize VR and disposal options. An evaluation of system laydown plans should address the ability to effectively remove radioactive, contaminated membranes, and install replacements without incurring membrane damage. Membrane disposal costs may be less than ion exchange resins because of relatively simple volume reduction.

5.6.1.3 Operation

One of the most critical aspects of membrane operations is operator proficiency. Similar to evaporators, membrane systems require careful operator oversight for successful operation particularly during initial startup and establishment of an operational experience database. Industry experience clearly demonstrates the need for providing operators with in depth chemistry and system and membrane design and operation knowledge.

Membrane performance needs to be periodically monitored, and it is important to monitor the individual membranes. The system controls can be located locally, or dependent on the technology employed, located in a remote location such as a RW control room. The control technologies range from manual panels to PLC controllers. Liquid samples should be filtered with a 0.1µm filter and measured and trended for activity breakthrough. Recommended sampling frequency ranges from monthly to quarterly depending on throughput volume, influent waste characterization.

Support from the station chemistry organization is critical to effectively analyze and assess influent waste stream characteristics and potential fluctuations. That information is required for assessing membrane performance, predicting cleaning cycles, and also for assessing related media performance.

Chemical cleaning will normally be required on a periodic basis - determined by influent quality, membrane design, and operational experience. This cleaning will also help to minimize activity buildup. As discussed previously, pretreatment is a key element of successful processing using a membrane-based system. The system operation should include careful oversight of that process, minimizing the potential for challenging membrane materials with undesirable inputs.

Membrane process components including prefiltration, membranes and reject will concentrate activity. The potential for significant dose rate increases in adjacent areas exists. Plans for monitoring and mitigation can alleviate the potential for long term, undesirable radiation levels. Those plans may include elements such as remote monitoring capabilities, defined media changeout dose rates, defined membrane cleaning dose rates, and additional shielding options.

5.6.1.4 Membrane Cleaning and Changeout

Periodic membrane cleaning may be required to remove a buildup of undesirable chemical impurities and/or activity that can irreversibly foul or damage membranes. In addition to periodic cleanings chemical cleaning will normally be required prior to replacing membranes to reduce membrane dose rates. The cleaning method is dependent on the membrane material and design and foulants and may be performed using acid, caustic, and powdex. This process may require soaking and recirculating membranes in an acid and caustic solution to loosen and dissolve the foulant. Powdex may be required and is recirculated through the membranes providing an abrasive cleaning mechanism. Depending on the age of the membranes and amount of buildup several sets of cleanings may be required.

The cleaning will generate a waste stream that captures the removed activity and is typically high in insoluble impurities. The resultant chemical cleaning waste will require neutralization and on or off site treatment to produce a waste form acceptable for disposal or storage.

> **NOTE:** The chemical cleaning process is time consuming and the resultant waste stream can be difficult to deal with.

Industry experience has shown that membranes with a long service life and high dose rates can be very difficult to clean. If the cleaning process is effective, membrane replacement will result in minimal personnel exposure.

When a membrane becomes irreversibly fouled or exhausted, it will require replacement.

> **INDUSTRY EXPERIENCE**: At one station, silica concentrations exceeded 120 ppm and precipitated onto the membrane material. The effects were an irreversible fouling of the membranes, high differential pressure, and mandatory replacement was unexpected. The membrane change was rather expensive and resulted in additional exposure to the site staff.

It may be advisable to change membranes periodically before failure because the filter dose rates may be too high to change the filter. This also prevents extensive chemical cleaning during the last stage of the filter life.

Prior to removal, evaluate chemically cleaning the membrane to reduce activity levels to an acceptable level for handling, packaging and disposal. The costs associated with chemical cleaning and residual disposal should be less than the benefit derived by cleaning.

5.6.1.5 Reject Packaging, Volume Reduction, and Disposal

Currently, the majority of membrane rejects are treated using one of three techniques:

1. The rejects are dried using thermal processes prior to disposal.—Thermal VR and packaging processes either require additional on-site equipment and processes, or shipment of the slurry to off-site vendors for processing. This is the only single step option that creates a final product suitable for storage or disposal.

2. The rejects can be routed through a tank or waste container loaded with partially depleted ion exchange media. The tank decant is routed to waste collection tanks for normal LRW processing.

3. UF rejects can be filtered—Filtration of the reject can be accomplished with cartridge filters or pre-coat filters. At least one vendor provides a disposable drum sized HIC with integrated cartridge filters. Similarly, a small precoat filter has been used to treat UF reject. Diatomaceous Earth (DE) filter aid has been successfully employed to treat membrane reject (note that cellulose fiber was not efficient for this process). Spent filter aid can be remotely backwashed into a waste container for de-watering or solidification prior to storage or disposal.

4. For some systems, the reject may be mixed with existing radwaste.

INDUSTRY EXPERIENCE:
1) Several stations use liners of spent condensate polishing resin to treat membrane reject similar to an atmospheric demineralizer configuration.
2) Spent resin does not clean up UF reject at all plants. Some plants choose not to handle high dose rate drums or small HICs
3) Pre-coat filter treatment of UF reject has resulted in 2 ft^3 of DE that removed 7 Ci from 10,000 gallons of plant resin sluice water.

Membrane reject packaging and disposal options are primarily controlled by the activity and drying/VR processes. The following also impacts process use and cost:

- Reject solids density - wt. %.
- Plant structural and space constraints.
- Available plant drying/VR equipment.

- Available plant handling equipment for high activity drums
- Available vendor services for on and off-site drying/VR.
- Liquid reject packaging and transport.
- Disposal pricing structure.
- Disposal availability (long and short term).

5.6.1.6 Membrane Waste Packaging, Volume Reduction, and Disposal

Properly sized membranes can be disposed in currently available waste packages for further off-site VR and/or disposal. Alternatives such as segmentation may be required for larger elements. Low dose membranes are typically eligible for thermal destruction or supercompaction resulting in a significant VR. When properly managed (e.g., influent quality consistent, performance and dose rate monitored, and cleaned on a regular basis) the majority of membranes are very low activity. They are typically classified as DAW.

5.6.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

5.6.2.1 Influent Characterization, System Configuration, and Membrane Selection

1. Membrane system suppliers should provide a comprehensive characterization plan. It is highly recommended that the station review and implement that plan with technical assistance provided by the supplier to ensure samples are representative of the potential waste stream(s) and that the associated analyses are performed to meet the supplier's need.

2. The general waste stream characteristics and pretreatment needs should be evaluated prior to membrane selection and system design. The characterization parameters listed below represent an ideal program. For most applications it is not necessary to evaluate all of these parameters; the characterization program should be based on vendor recommendations augmented by plant waste stream knowledge. To the extent practical and where applicable, the high, median, and low values should be identified.
   - Process volume.
   - Process flow rate
   - pH
   - Cations
   - TSS
   - Total and isotope specific activity.
   - Magnesium

- TDS
- Conductivity
- Calcium
- Iron
- Turbidity
- Sulfates
- Anions
- TOC
- Silica
- Chlorides
- Temperature
- Streaming current detector (SCD) – measures the electrical current generated by moving ions in a high velocity stream.
- Silt Density Index (SDI) – measures the rate of fouling of a 0.45µm filter membrane – test is not conclusive, but is considered a benchmark.
- Particle size and abundance using various techniques.
- Concentration of other chemical impurities (ie.g., boron, sulfates, iron, closed cooling water system corrosion inhibitors).
- Microorganism abundance.
- Anticipated variations in influent quality.

3. Working with the supplier, determine the desired system performance parameters. As part of that assessment include the following:
   - Desired effluent characteristics including:
     - Chemical
     - Activity
     - Site staff exposure
     - Liquid effluents exposure
     - Gaseous effluent activity and exposure (impact on gaseous from modifying liquid strategy).
   - Membrane flux and desired impurity rejection rate.
   - Permeate recovery (permeate flowrate divided by feed flowrate) required to meet plant needs - normal and surge volumes adjusted for membrane availability (membranes will be taken out of service for cleaning or replacement).
   - Materials of construction - cellulose acetate, thin film polyamide, or polysulfone membrane material is best suited for your application.

- Membrane housing length and diameter (membrane size)
- Number of membrane stages
- Pipe size
- Minimum flow rate to preclude membrane fouling.
- Design pressure.
- Verify that recommended chemical cleaning's waste treatment and/or disposition is compatible with federal, state and local regulations and is cost effective.

4. Working with the supplier, define process controls
   - Operator oversight and ALARA
   - PLC and remote monitoring
     - panel location
     - reliability
     - LAN interface and cable routing
     - alarm
     - real time operating parameter
     - emergency shutdown
     - automatic logging
     - reports, graphics
5. Working with the supplier, determine the desired system design considerations. As part of that assessment include the following:
   - Hard piping for high pressure segments to preclude hose failures.
   - Compatibility with existing feed tanks, pumps and system piping.
   - Process skid layout to facilitate mobilization, operation, maintenance, chemical cleaning, membrane changeout, and demobilization.
   - Component system designed for maintenance and repairs to be done ALARA.
   - Shielding requirements to maintain general area dose rates ALARA.

> **INDUSTRY EXPERIENCE**: A modular design at one station resulted in a very efficient installation. However, that specific design did not include remote location of gauges and instrumentation, nor access to critical "wear" components such as pumps and frequently cycled valves. This in turn resulted in high personnel exposure during maintenance and calibration related evolutions.

> **CAUTION:** Ensure the system's minimum flow rate will be sufficient to preclude membrane fouling.

> **INDUSTRY EXPERIENCE**: One station experienced high dose rates in the vicinity of their RO skid. Floor loading limits precluded their ability to install additional temporary shielding. This resulted in very high operator exposure.

– Component accessibility for maintenance and testing

> **INDUSTRY EXPERIENCE**: Several stations have experienced difficulty and/or high personnel exposure related to repairs to pumps, valve repairs, and instrumentation troubleshooting and replacement on systems where these components were not sufficiently shielded from membrane housings and feed tanks.

– Sample panel location, purge requirements, and sampling evolution ALARA impact

  o Ensure the slipstream sampling lines are large enough to preclude clogging with solids that would impact the effectiveness of sample results, and/or remote monitoring or injection technologies.

  o Consider remote sampling panels for reducing operator/chemist exposure.

– Lifting lugs of sufficient strength to lift the vessel vertically

6. Working with the supplier, develop a detailed summary of plant services required to support equipment operation. This includes, but is not limited to:

   – Remote audio and video monitoring

   – floor loading

   – electrical

   – air

   – water

   – ventilation

   – drains

   – media replacement

7. Evaluate membrane VR and disposal options that minimize disposal costs to the extent practical without compromising membrane performance.

5.6.2.2 Operation

1. Define a plant staff single point of contact to coordinate operation, chemistry, radwaste, and radiation protection efforts.

2. Develop a station plan that addresses required changes to operating philosophies including drain and chemical controls, system draining, etc. The plan should also include a summary of the system's limitations and projected benefit to the station and a plan for educating the station and contract staff.

3. Require the supplier to provide a <u>written plan</u> addressing System operation and processing secondary, solid and/or concentrated wet waste generated as a result of operating the processing system. The plan should include considerations related to:
   - ALARA - system installation, operation, and waste handling
   - All vendor supplied equipment
   - Installation
   - Operating personnel
   - Technical support - installation and operation
   - Materials
   - Procedures
   - Quality controls
   - Startup training

4. Initially, requiring the supplier to provide a qualified operator with at least 3 years of applicable system operating experience.

5. Selecting and training a dedicating crew to operate the system. The team should include a chemistry process expert and should be trained by the supplier to ensure design and operation details are clearly communicated. This option also results in capture of that supplier's industry lessons learned.

6. Carefully monitor plant evolutions and waste inputs to minimize challenges to the system. Influent waste chemistry parameters should be analyzed on a routine basis. Refer to waste characterization guidance in this section for related considerations. **<u>This is a critical aspect of successful membrane processing</u>**.

7. Periodically evaluate individual membrane's performance. Liquid samples should be filtered with a 0.1µm filter and measured and trended for activity breakthrough. Recommended sampling frequency ranges from monthly to quarterly depending on throughput volume, influent waste characterization.

8. Contact other stations using membrane processing to capture current lessons learned.

9. Perform chemical cleanings based on manufacturer's recommendations, system performance and the plant specific experience base once established.

5.6.2.3 Membrane Cleaning and Changeout - RO

1. Evaluate chemical cleaning benefit prior to changeout. Note that changing membranes periodically before failure minimizes the need for extensive chemical cleaning during the last stage of the filter life. As part of that analysis, consider the following:
   - Chemical procurement costs.
   - Chemical waste treatment and/or disposition.
   - Membrane packaging, VR and disposition options at pre- and post-cleaning activity levels.
   - Labor support costs.
   - Expected exposure reduction.
   - Station cost per person-Rem.
2. Working with the supplier, develop chemical cleaning procedures and controls including the following:
   - A written plan describing their use, expected frequency, and expected processing delay/interruption time periods
   - A written plan describing excess and/or residual chemical disposition.
   - Material Safety Data Sheets (MSDS) for all chemicals used.
   - Compliance plan for all MSDS control and safety requirements
   - Double wall containment piping where determined appropriate.
3. Verify that membrane changeout considerations are addressed when designing the system configuration and laydown footprint. As part of that assessment consider:
   - Physical access and maneuverability.
   - Personnel exposure controls.
   - Contamination controls.
   - Membrane transport to shipping packages.
   - Successful replacement membrane installation.
4. Perform membrane changeouts based on manufacturer's recommendations, system performance, activity and the plant specific experience base once established.
5. Evaluate changing membranes periodically prior to failure to minimize personnel exposure during changeout and packaging. Extended runs may result in dose rates that create excessively high work area dose rate. This approach also minimizes the need for extensive chemical cleaning during the last stage of the membrane life.

5.6.2.4 Reject Waste Packaging, Volume Reduction, and Disposal

1. For all options, carefully evaluate all factors including:
   - Safety analysis (UFSAR and industrial)
   - Final concentration density - wt. %.
   - Plant structural and space constraints.
   - Available plant drying/VR equipment.
   - Available vendor services for on and off-site drying/VR.
   - Level of effort and resource impact for liquid reject packaging and transport.
   - Disposal pricing structure.
   - Cost associated with packaging, shipping, permits, and treatment costs relative to other options.
   - Equipment cost
   - Disposal availability (long and short term)
   - Procedure and other document revision
   - Operator training and qualification
   - Space requirements
   - Shielding requirements
   - Site staff exposure
   - Support services (e.g., air, water, electric, HVAC)
   - Secondary waste generation
2. For on-site thermal treatment:
   - Thermal VR and packaging processes require remote handling equipment for high activity drum packaging, staging/storage and cask loading.
3. For off-site thermal treatment:
   - Review the shipping cask Certificate of Compliance (C of C) to ensure compliance with restrictions related to free-standing liquid and total package activity.
4. When routing reject through a tank or waste container loaded with partially depleted ion exchange media:
   - Evaluate the influent and effluent streams for effectiveness at a defined interval.
   - Ensure the final waste product (resin) is properly characterized to ensure compliance with waste classification, shipping, off-site VR, and disposal regulations and/or requirements.
5. For UF Reject
   - For filtration in a HIC

    - Insure remote handling equipment for high activity drum sized HIC storage and cask loading are available
    - Insure waste classification issue for the HIC are addressed
  - For filtration in a vessel
    - Insure high activity filter handling equipment (e.g., filter casks, hoists, etc.) are available
  - For filtration via a pre-coat filter.
    - Body feed of precoat will reduce the total waste generated and extend filter run time
    - The use of Diatomaceous Earth (DE) versus cellulose filter aid to remove agglomerated submicron particles

5.6.2.5 Membrane Cleaning and Changeout - UF

1. Working with the supplier, develop chemical cleaning procedures and controls including the following:
   - A written plan describing their use, expected frequency, and expected processing delay/interruption time periods
   - A written plan describing excess and/or residual chemical disposition.
   - Material Safety Data Sheets (MSDS) for all chemical's used.
   - Compliance plan for all MSDS control and safety requirements
   - Double wall containment piping where determined appropriate.
2. Evaluate chemical cleaning benefit prior to changeout. As part of that analysis, consider the following:
   - Chemical procurement costs.
   - Chemical waste treatment and/or disposition.
   - Membrane packaging, VR and disposition options at pre and post cleaning activity levels.
   - Labor support costs.
   - Expected exposure reduction.
   - Station cost per person-Rem.
3. Verify that membrane changeout considerations are addressed when designing the system configuration and laydown footprint. As part of that assessment consider:
   - Physical access and maneuverability.
   - Personnel exposure controls.
   - Contamination controls.
   - Membrane transport to shipping packages.
   - Successful replacement membrane installation.

4. Perform membrane change outs based on manufacturer's recommendations, system performance, activity and the plant specific experience base once established.

5.6.2.6 Membrane Waste Packaging, Volume Reduction, and Disposal

NOTE: When properly managed (e.g., influent quality consistent, performance and dose rate monitored, and cleaned on a regular basis) the majority of membranes are very low activity. They are typically classified as DAW and can be easily volume reduced and packaged.

1. For all options, carefully evaluate all factors including:
   - Safety analysis (UFSAR and industrial)
   - Plant structural and space constraints.
   - Available plant VR equipment.
   - Available vendor services for on and off-site VR.
   - Disposal pricing structure.
   - Cost associated with packaging, shipping, permits, and treatment costs relative to other options.
   - Equipment cost
   - Disposal availability (long and short term)
   - Procedure and other document revision
   - Space requirements
   - Shielding requirements
   - Site staff exposure
   - Support services (e.g., air, water, electric, HVAC)
   - Secondary waste generation
2. Review station activity limits relative to membrane dose rate, VR and disposal. Where applicable, adjust limitations to maximize the use of VR techniques and minimize disposal costs.

CAUTION: Ensure changes to packaging strategies remain in compliance with the PCP, and container C of C and procedures.

3. Analyze the disposal fee structure to define the most cost effective membrane and reject packaging density and activity. Include as part of that analysis items such as density and activity changes on transportation fees and packaging and disposal options.

   When evaluating waste packaging requirements, include the following:

- Cost
- Container material, size, and weight.
- Stabilization requirements.
- Density impact.
- Reject transport and shipping container disposition.
- VR and packaging efficiency.
- Curie content.
- Dose rate.
- Packaging equipment requirements.

4. Evaluating increases in waste classification because of VR and/or increased packaging efficiencies to ensure the parallel increase in packaging and disposal costs is less than the cost associated with the originally higher volumes at a lower specific activity and waste classification.

5. Analyze spent membrane VR practices to ensure that the increased packaging efficiency does not increase the specific activity of nuclides such as carbon-14 nickel-63 and TRU, to levels that result in Greater Than Class C waste.

6. Analyze the site structural layout to ensure membrane VR, packaging and transport preparation evolutions are optimized. As part of that evaluation consider alternate use of existing facilities, addition of simple, cost effective alterations, and removal of equipment "retired in place" for optimizing the use of alternate space.

5.6.3 Hollow Fiber Filtration

In recent years, Hollow Fiber Filter (HFF) technology has been widely used for Japanese (and other) BWR and PWR plants in Condensate Filtration Systems (CFS) or for LRW processing. However, US experience with this technology in LRW processing applications is very limited. Therefore, in spite of its membrane based operation, the following information is included in this section as stand alone data; the direct correlation to the preceding membrane information may exist, but is not clearly defined.

HFF elements are constructed using various polymer materials such as polyethylene (PE), polysulfone, polyolefin and polyvinylidine fluoride. A HFF system is made up of many cartridge filter modules that are formed by bundling thousands of hollow fiber membranes. The large filtration area per volume allows the system to be very compact. The technology also does not require a precoat media, therefore it does not generate secondary waste.

5.6.3.1 Design and Configuration

Hollow fiber membrane typically has 0.1-micron pores on its outer surface. These fine pores remove suspended particles in the radwaste water. The outer diameter of a typical hollow fiber strand is 1.2mm and inner diameter is 0.7mm. The HFF single piece cartridge module contains of 4,200 PE hollow fiber membranes with a total filtration surface area of 24 m^2 per module. These bundled hollow fibers are covered with a hard outer shell made from polypropylene. The shell protects the fibers from any damage during shipping, handling, and installation. Figure 5-6 and Figure 5-7 illustrate a typical HFF membrane and vessel configuration.

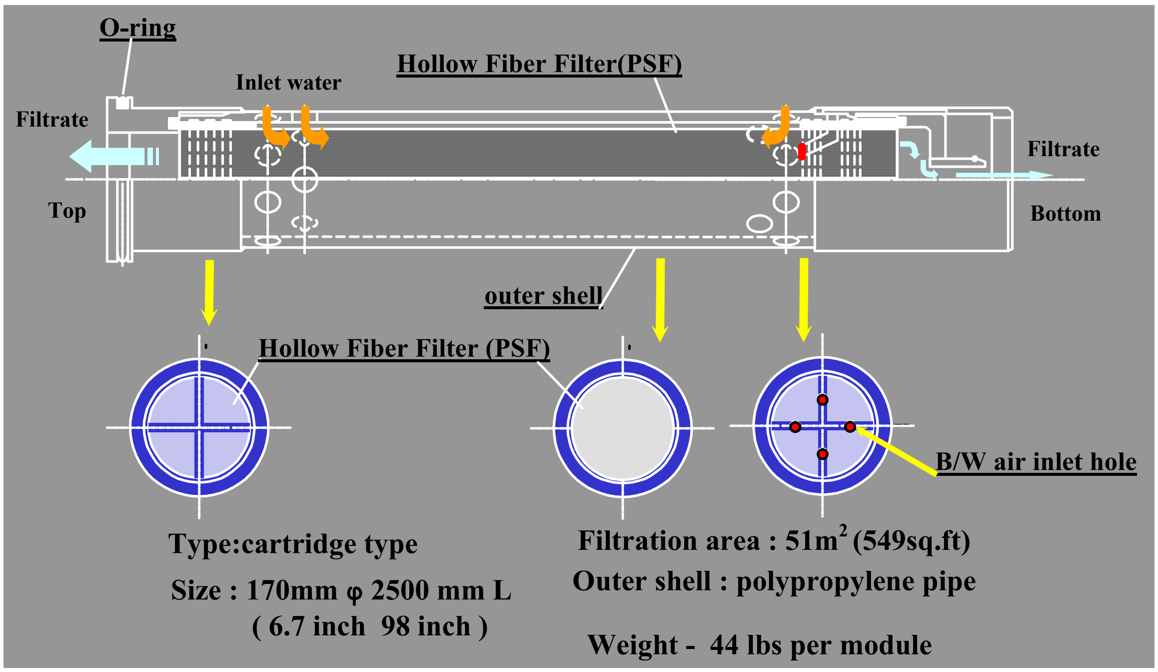

Figure 5-6
Typical Hollow Fiber Filter Design

Source: Organo

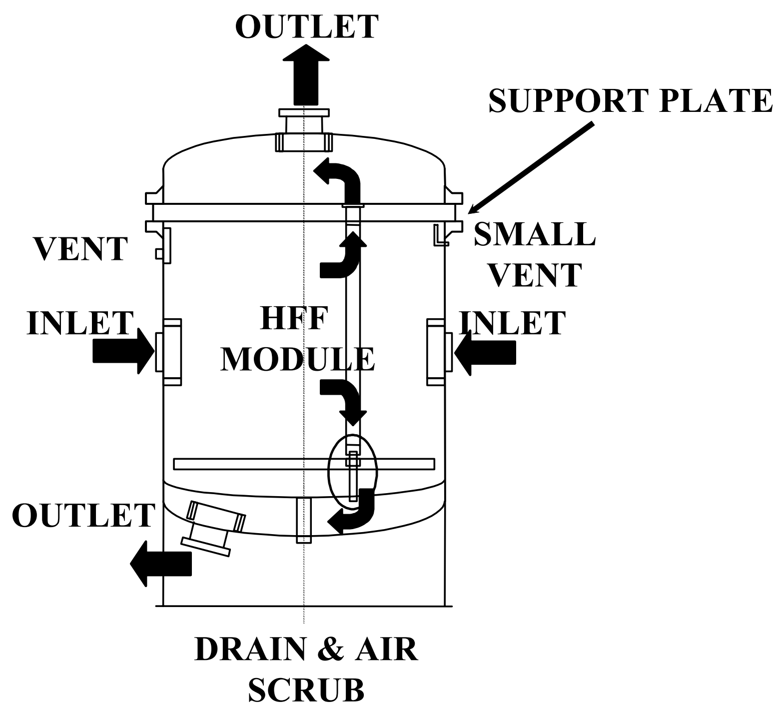

Figure 5-7
Typical HFF Vessel Configuration

5.6.3.2 Performance

HFF system performance will vary based on influent characteristics, operating history, media/element type, and other impact factors. Table 5-2 is intended to illustrate the relative performance for a HFF system.

Table 5-2
Typical HFF Performance

Parameter	**Specification**
Flow Rate	326 gpm (74 m^3/h)
Vessel Diameter	37.4 inch (950 mm) ID
Vessel Height	138 inch (3500 mm) H
Module (Element) material	Polypropylene
Number of Modules (Elements)	15 / vessel
Precoat material	None
Filtration Area	3875 ft^2 (360 m^2)
Flux	0.082 gpm/ft^2 (0.2 m/h)
Backwash Method Air-Surge	H_2O_2 Soaking Wash
Backwash Frequency (Japan - actual performance)	16 times / year

5.6.3.3 Cleaning

The cleaning methods are accomplished in two basic ways, physical cleaning and chemical cleaning. The basic methods of physical cleaning are as follows:

1. Air scrubbing backwash

   The air is added to bottom of vessel and the air bubbles travel from bottom to top along each hollow fiber. These air bubbles vibrate solids (iron oxide, etc.) off the fiber surface.

2. Air surge backwash

   Pressurized air is introduced to the filtrate side of vessel. The filtrate water traversed the inside of the hollow fibers and is exhausted to the outside to remove the collected solids on the outer surface of the fibers.

When the differential pressure (dP) rate of increase is significantly high due to organic fouling and the initial dP was not recovered sufficiently by air/water scrubs, chemical cleaning with hydrogen peroxide has been implemented to augment that physical cleaning.

5.6.4 Critical Performance Considerations

The Japanese experience indicates that similar to other technologies, there are several challenges that impact HFF processing.

A rapid initial increase in dP caused by off standard waste fluids has been solved by the following measures:

- Soak and wash with H_2O_2 when initial dP reaches 29.0 psid (0.2 MPa).
- Minimize influent bacteria or polyelectrolyte concentration that foul the upstream HFF membrane surface.

Degradation of HFF tensile elongation can be mitigated by the following measures:

- Minimize the frequency, concentration, and duration of chemical cleanings.

Careful operational oversight for HFF can help to ensure that the lifetime of the filter module will be more than 5 years.

5.6.5 HFF Summary

The HFF system does not require precoat, and industry experience indicates that if properly operated and influent water quality is controlled, the system will require fewer backwash operations than precoated systems. This reduces the volume of solid radwaste generated, thereby reducing the associated costs, labor requirements, and personnel exposure. The HFF is a proven LRW processing technology that produces a high quality effluent stream.

5.6.6 Cross Reference(s):

None

5.7 Program Element: Precoat Filters

5.7.1 Program Impact

Precoated filters require a detailed understanding of the septa and media. Refer to the "Cross References" listing at the end of this section for more detailed guidance.

Precoated filters are used as a stand alone filter/demineralizer or as prefiltration and demineralization prior to a deep bed demineralizer. When properly utilized, they are effective processing tools, however their use can be costly consuming large volumes of media. Typically, condensate filter/demineralizer systems generate the most significant radwaste volumes.

The effectiveness of this process is dependent on a number of variables that are applicable to any precoat filter use including the following:

- Influent impurity concentration
- Influent impurity morphology
- Vessel flow rate
- Vessel flux
- Temperature
- Organic concentration (TOC)
- Precoat material
- Premix or component precoat media
- Precoat overlays and/or underlays
- Resin ratio
- Fiber type
- Precoat quantity
- Precoat quality/concentration/rate (uniformity)
- Element type
- Differential pressure
- Backwash type
- Maintenance history (modifications)
- Body feed

- Ability for media to settle in phase separators in the allotted time period

Failure to adequately address these issues can result in:

- A reduction in effluent quality.
- Increased processing costs.
- Irreversibly fouled filter septa.
- Increased waste disposal volumes.
- Increased personnel exposure.
- Phase separation and/or sludge management issues.

This section addresses several program elements applicable to both radwaste and condensate processing systems. Detailed condensate filter/demineralizer guidance can be found in Appendix A, Reference 7.

5.7.1.1 Media Selection, Blending and Loading Logic

Similar to cartridge filters, prior to media selection, the process stream characteristics, process function and goals must be defined. Several additional factors must also be considered that are specific to precoat.

Media may be procured as an “off-the-shelf” blend or the ratio of cation resin, anion resin and fiber can be custom blended to the plant specifications based on chemical or physical characteristics. Previously, powdered resin premix products had traditionally been available only in stoichiometric ratio. A change by resin suppliers to produce higher cation to anion ratio premix products allows plants to develop custom ratios where required to optimize the precoat of individual components to meet site specific objectives. However, a small number of plants continue to mix the precoat materials on-site. This approach can produce desired precoat blends; however, it does have the undesirable aspect of introducing an element of variability into the precoating process.

During the service run the resin precoat shrinks as the ion exchange resin is exhausted. This shrinkage causes cracking of the precoat. The resultant precoat voids allow impurities either to pass to the filter demineralizer (F/D) effluent or become imbedded in the filter element. Precoat shrinkage can also cause the precoat to shift from depth to surface filtration.

Powdered precoat media can be volume reduced and disposed using a variety of options. The media can be vacuum compressed in a shipping liner, incinerated, thermally treated, and at one disposal site, very low activity media can be disposed directly on land without packaging. The chemistry of the fiber used in blends have been found to be a significant factor affecting biogassing in solid wet waste containers.

5.7.1.2 Septa

Stainless steel septa are historically the elements of choice for radwaste applications, however, substitute poly based materials has rapidly grown acceptance in the industry. Stainless steel has the advantage of being able to be steam cleaned or washed with high pressure fluids with little or no resultant damage. Stainless steel is also less susceptible to oil fouling when compared to the new generation of advanced, slotted/pleated filter septa, however, the benefits associated with new, advanced septa materials and design discussed in the following section, typically outweigh the few benefits of stainless steel.

5.7.1.3 Pleated

Pleated elements provide significant filtration area increases, up to a factor of 20 when compared to radial surface area of a standard wrapped element of similar diameter and length. In using a pleated element the individual vessel flux can be reduced from close to 4.0 gpm/ft^2 to approximately 0.2 gpm/ft^2. When using pleated elements in precoat service, the filter elements can be used to remove the impurities and subsequently, the precoat needs to be porous enough to allow the corrosion products to pass to the membrane. Otherwise, the limiting factor to a dP endpoint will be surface filtration on the precoat layer.

In some cases, the amount of precoat material used on a pleated element has been reduced to roughly one-third of the wound element value. The fiber component of the precoat material has also been removed for pleated elements. In fact, the use of cellulose fiber in the precoat of these elements is suspected to reduce run lengths.

Membrane material for pleated elements to date have been polyester, polysulfone, polypropylene, and Kevlar.

Membrane filters can be operated as depth filters. The increased surface area of pleated elements when compared to wound elements allows for long cycle lengths.

Finally, pleated filter elements offer the benefit of 100% thermoplastic materials of construction. These materials can be incinerated or shredded, increasing radwaste disposal options.

5.7.1.4 Resin Leakage

All powdered resin vessels equipped with a knife edge or single ‘O’-ring seals on their elements leak resin. This is not a significant concern in most radwaste applications as the recycled liquid is typically reprocessed in the condensate polishing facility prior to introduction to feedwater systems. Additionally, the precoating process tends to seal leaks with the precoat material itself as the layer builds, however, any leakage path sealed in this manner will be vulnerable to future leakage during flow perturbations.

5.7.1.5 Operation

The majority of precoat filters are operated with a blend of fiber and ion exchange material, however, new membranes are typically being operated solely with ion exchange material. The filters are used for processing floor drain and equipment drain wastes. The effectiveness of the filtration is dependent on a large number of variables aside from the process stream characteristics.

Table 5-3 clearly portrays this using equipment drain precoat filter throughout data from ten plants.

Table 5-3
Comparison of Radwaste Equipment Drain Precoat Filter Media Performance

Station	Gallons Processed per Cu. ft. Media Expended
B-26, 500 Mw_e	12,000
B-19, 1100 Mw_e	19,400
B-5, 770 Mw_e	29,500
B-13, 1055 Mw_e	36,000
B-12, 1040 Mw_e	56,000
B-27, 1100 Mw_e,	56,400
B-6, 540 Mw_e	62,000
B-8, 760 Mw_e	64,400
B-11, 1030 Mw_e	70,000[A]
B-4, 760 Mw_e	157,000

Several of the more important factors influencing filter performance are addressed in the following material.

5.7.1.6 Precoat Application

One of the more critical elements of successful precoat operation is the ability to create a precoat layer distributed evenly over the available surface area. Most plants precoat to the manufacturer’s recommendation of 0.20 dry # per ft^2 of element surface area. Some plants operate at a higher precoat loading to increase ion exchange capacity. Others using newer elements operate with reduced precoat dosages. The maximum amount of precoat material that can be applied is based on the thickness of the precoat material as applied on the element and the element to element spacing within a particular vessel.

Exceeding this guidance can result in severe element damage if bridging occurs. Lower precoat loading is associated with a relatively new technology of minimum precoating.

Modified Precoat System

Industry experience indicates that if the resin/fiber mixture is deposited on the filter element over a very short period of time, the potential for uneven and/or cracking precoat layers increases. Typically, element inspections indicate uneven precoat application using the standard precoating process. This uneven/cracked precoat condition can allow passage of soluble impurities through the septa as well as allow insoluble impurities to penetrate the element material itself. This too, creates an increasing degree of element plugging (high clean dP). These phenomena will not only reduce system run lengths and lower effluent quality, but will also increase element replacement frequency.

Modified precoating employs a system capable of supplying precoat in a dilute, constant feed slurry.

> **INDUSTRY EXPERIENCE:** The use of a precoat pump upgrade targeting increased precoat flux has been successful implemented. European experience with precoating at a higher flux has demonstrated increases in run length to a dP endpoint.

Bodyfeed

Bodyfeed is the process of slowly adding additional precoat material to the inlet side of a filter/demineralizer vessel during processing operations. A smaller initial precoat layer is applied to prevent element bridging. The additional precoat material acts to fill in cracks in the precoat or lightly precoated areas. This can extend filter run lengths.

Outages

During outage periods the filters are challenged by high volumes of reduced quality liquid waste inputs. This negatively impacts processing operations frequently resulting in reduced effluent quality for recycle or release. Additionally, processing low quality liquid wastes will result in more rapid filter fouling, increasing process related costs and waste disposal volumes.

The majority of precoat filters used in radwaste applications are operated to a predetermined dP endpoint. The filter dP directly impacts the performance of the filter modifying its ability to effectively process the waste stream at the design flow rate.

5.7.1.7 Backwash

Complete removal of spent precoat material is one of the major factors contributing to long element life and the ability for a filter/demineralizer system to continue to produce high quality effluent. An effective backwash is also important to maintain consistent run lengths as the elements age. The need to perform a backwash is determined by reaching a defined endpoint dP, or as a result of chemical breakthrough.

Hydro-pneumatic

The original hydro-pneumatic backwash was designed for fossil-fired systems. The quantity of backwash waste was not as much of an issue in the early filter/demineralizer systems as it is today. A normal hydro-pneumatic backwash uses 18 to 23 gallons of water per square foot of surface area.

Air volumes used in the backwash sequence were low, generally less than 1.0 standard cubic foot per minute (SCFM) per square foot of surface area.

Mod3

The Mod3 backwash was developed to reduce the backwash volume in BWR plants. Waste water volume per backwash was reduced to approximately 15 gallons/square foot of surface area.

The reduction in waste water volume was achieved by increasing the air scouring rate to 1.5 SCFM per square foot of surface area. The duration of the aeration steps were increased to take advantage of the increased scouring energy.

With Mod3, air and water are injected simultaneously into the vessel plenum while the upper filter chamber is vented. Water and air are injected simultaneously during all the cleaning steps and the level in the filter area is raised and lowered by cycling the vessel drain valve.

The effectiveness of this backwash method depends primarily on local turbulence produced when air escapes from the element just below the surface of the water. The water flow is used to carry the spent precoat material and corrosion products to a receiver tank.

Air Surge

The air surge modification was designed to extend element life by increasing backwash power using high energy, short duration bursts of air. It also significantly decreases the amount of waste water generated per backwash.

Initially the vessel is vented and drained. This draining step removes some of the precoat. A small flow of backwash water is applied to keep the vessel plenum filled. A fast acting valve allows a surge of air equivalent to 12 SCFM per square foot of surface area to enter the plenum area for approximately 2 seconds. The surge drives the water in the vessel plenum through the elements at high velocity. The standard backwash consists of eight surges. Maximum cleaning efficiency is achieved by using the drain valve to control the level in the filter chamber before each air surge.

Air Bump

The air bump backwash is prevalent in top tube sheet vessels. The air bump sequence starts with draining the vessel dome to the tube sheet level. Air is valved into the dome until it reaches the backwash air system pressure. A fast acting drain valve opens and the air pressure in the dome drives the water in the filter chamber out of the vessel. The drain valve opening speed is important in the overall efficiency of the air bump backwash. The faster the valve opening speed, the higher the overall energy of the backwash.

The air bump sequence is usually repeated for a total of 2 or 3 air bumps per backwash. The number of air bumps is kept to a minimum due to the need to fill the filter chamber for each air bump. This is required to pressurize the vessel dome. As a result, the number of repeats increases the amount of backwash waste water volume to be processed.

Following a backwash cycle, the clean dP is an indication of the effectiveness of the backwash process and the septa condition. An upward trend in the clean dP is indicative of less than desirable backwash performance, or irreversible septa fouling. This may require changes to the media specifications, procedures, hardware, or septa cleaning/replacement.

5.7.1.8 Backwash Waste Processing

While it is apparent that precoat filtration is effective, the process also produces a dual component waste stream. The backwash liquid and accompanying solids require additional processing prior to solids disposal.

Separation of these materials is typically accomplished in a phase separator or separate waste container, allowing solids to settle and decanting "clean" liquid for reprocessing and recycle or release. The iron oxide and other solids present in the waste stream is most effectively settled in slurries containing both resin and fiber precoat material. Minimum and non precoat filters generate less-to-no precoat, and solids settling efficiency is reduced. The effectiveness of the phase separation process is primarily dependent on retention time and the chemical attributes of the impurities present in the waste solution.

5.7.1.9 Operator Training

The quality of training provided to system operators can significantly impact the effectiveness and cost of precoat filtration. Inadequate training can result in inconsistencies with precoat application, backwash, effluent quality, radwaste generation, and overall system performance.

5.7.1.10 Septa Cleaning and Changeout

Septa cleaning is performed at several stations as a routine PM measure in an attempt to prolong septa life. The periodicity is determined by trending clean dP, or by using a predetermined time period based on historical performance (i.e., annually).

Chemical cleaning is usually not an option due to the potential for generation of a mixed waste. Steam cleaning or sludge lancing is sometimes used to restore the element's performance. Some plants have used, with mixed results, ultrasonic baths with a solution of muriatic or phosphoric acid to clean the elements, neutralizing the generated waste prior to treatment and/or disposal.

The changeout criteria for septa is typically based on a predetermined upper limit for clean dP. The waste septa radiation and activity levels vary by waste stream and unit and have corresponding variations in VR and disposal options. Most filter hardware is disposed rather than recycled in an effort to maintain personnel exposure ALARA.

As radwaste disposal costs increase, this practice is routinely being challenged. When handling waste septa, the use of remote or extension tooling similar to that recommended for cartridge and bag filters can be effective for maintaining associated personnel exposure ALARA.

5.7.1.11 Waste Packaging, Volume Reduction, and Disposal

Similar to other processes, precoat filter waste VR, packaging and disposal options are primarily controlled by the media or septa activity. Additionally, these program elements are impacted by:

- Plant structural and space constraints.
- Waste concentration averaging.
- Chemistry of waste.
- Available plant VR equipment.
- Disposal availability (long and short term).
- Disposal price structuring.
- Vendor services available for use.

Precoat media has several options for VR both on and off-site. The media can be compression packaged on-site in the shipping container resulting in VR ratios of up to 1.8:1. Additionally, some precoat waste is eligible for alternate advanced VR technologies as they become commercially available.

Waste septa can be compacted, supercompacted, shredded, chopped, or thermally destroyed to decrease the waste volume or increase the waste density. The available options are dependent on septa dose rates and materials of construction.

5.7.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

5.7.2.1 Media Selection, Blending and Loading Logic

1. Use only premixed precoat products supplied by the manufacturer. These have been shown to provide increased throughput to a dP endpoint in most plants. The products are engineered by the suppliers to deliver the optimum floc for precoating of the filter elements. Proper floc size is an important parameter in ensuring a uniform precoat.

> **CAUTION:** Cellulose fiber has been linked to biogrowth problems. Polyacrilonitrile (PAN) fiber can be used to minimize this problem, but PAN fiber is significantly more expensive than cellulose fiber.

2. Specifying a premixed resin containing various percentages of fiber. The addition of fiber helps reduce precoat cracking. In addition to preventing cracking of the precoat, fiber also helps remove organic impurities which may not be ion exchangeable.

3. Sample each precoat to determine its effectiveness using a comparison of influent and effluent characteristics.

4. Obtaining direct technical support from the material supplier to evaluate and recommend precoat process improvements.

5. Evaluate the material relative to VR and disposal options.

6. Use carbon prefiltration or a carbon based overlay during outages to target TOC removal.

5.7.2.2 Septa

1. When using pleated elements in precoat service, the precoat needs to be porous enough to allow the corrosion products to pass to the pleated filter membrane. Otherwise, the limiting factor to a dP endpoint will be surface filtration on the precoat layer.

2. The pleated element precoat volume should be reduced to roughly one-third of the wound element value. The fiber component of the precoat material should also be removed for pleated elements.

3. Carefully evaluate the pore size selected for membrane materials. If the pore size of the membrane is too close to the size of the corrosion product being removed, the chance of imbedding corrosion products in the membrane pores exists. If the pore size of the membrane is too large, the corrosion product removal efficiency would be less than expected

4. Installation of innovative new tube sheet adapters for both top and bottom tube sheets that can eliminate resin leakage at the tube sheet to element interface.

5. Another hardware variation is a fixed core design. A 100% thermoplastic element can then be slipped over the fixed core to maintain structural integrity. The thermoplastic element can be incinerated or shredded for VR at the end of the element's useful life.

6. For top tube sheet installations, a double 'O' ring attachment has gained acceptance. In this configuration, double 'O' rings provide a positive seal and allow the filter to be constructed from 100% thermoplastics however, a new tube sheet and support grid may be required. As a result, spent filters can be incinerated or shredded for VR using this improvement.

5.7.2.3 Operation

1. Use a modified precoat system in conjunction with existing precoat equipment, a uniform precoat can be applied over the entire element surface area, thus reducing the potential for precoat cracking and element fouling. This technique results in longer process run lengths, increased element life, less variability in performance, and improved effluent quality.

2. If bodyfeed equipment is installed and not currently used, re-evaluate its use to maintain the precoat in a depth filtration mode for a longer period of time, extending the media run length.

5.7.2.4 Operator Training

1. The overall precoat process should be reviewed and analyzed. Based on that analysis, develop hands on training for operators, engineers and maintenance personnel to enhance process performance.

2. Utilize a pilot ***scale*** filter/demineralizer unit for conducting operator training. The scale unit should allow visual observations of the precoat and backwash processes. This would not only be a valuable training tool, it could also serve as a test facility for alternative precoat media, techniques and technology—making the tool invaluable for enhancing any F/D’s performance.

3. Provide fundamental chemistry training to operators to enhance their understanding of the importance of proper component operation.

5.7.2.5 Septa Cleaning and Changeout

1. Evaluate the use and effectiveness of steam cleaning or hydrolasing septa on a routine basis based on clean dP trends, or historical performance data.

2. Carefully comparing waste disposal, septa changeout and associated labor costs with ALARA “costs”, ensuring ALARA based changeout decisions are cost effective.

> **NOTE:** “Clean” filter differential pressure (dP) profiles should be established and not exceeded. Precoat, non precoat and minimum precoat filter/demineralizers are particularly susceptible to irreversible fouling that can result in elevated dose rates and increased personnel exposure.

3. Incorporating the use of remote and extension tooling, and shielded transfer bells in septa changeout evolutions as required by activity levels. Septa changeout can sometimes be performed semi-remotely for top tube sheet vessels. The bundle can be lifted from the service vessel and placed in a shielded container for decay. Depending on the type of element attachment mechanism, the elements can be loosened using long-reach tools.

4. Several stations have developed unique transfer mechanisms such as a vacuum assisted housing to waste liner transfer tube, or carousel transfer containers. The use of video

equipment is also frequently used for remote radiation protection monitoring and evolution recording for future task analysis and enhancement.

5. When establishing septa changeout criteria include ***VR and disposal options*** in the analysis. Lower activity septa can be effectively volume reduced and density increased to create an optimum waste form for cost effective disposal.

6. When establishing septa changeout criteria, include the impact of ***waste classification and disposal costs*** in the analysis. Increasing the septa activity through extended service without VR will increase disposal costs, therefore it ***may*** be more cost effective to perform septa changeout on a more frequent basis.

5.7.2.6 Waste Packaging, Volume Reduction, and Disposal

CAUTION 1: Ensure changes to packaging strategies remain in compliance with the PCP, and container C of C and procedures.

CAUTION 2: The bottom dewatering laterals on powdered resin liners can be dependent on capillary action. To ensure compliance with disposal site residual liquid criteria, it may be prudent to load a bead resin bottom layer first, acting as a buffer to preclude clogging the dewatering laterals.

1. Perform a safety analysis (UFSAR and industrial).

2. Evaluate all options for VR and disposal including in-container VR, shredding/chopping, compaction, incineration and pyrolysis.

3. Similar to the impact on alternate wastes, analyze the site structural layout to ensure media and septa VR, packaging and transport preparation evolutions are optimized.

4. Analyze the disposal fee structure to define the most cost effective precoat media and septa packaging density and activity. As part of that analysis include density and activity changes on transportation fees and packaging and disposal options.

   When evaluating packaging requirements, include the following:

   - Container material, size, cost.
   - Stabilization requirements.
   - Density impact.
   - VR and packaging efficiency.
   - Curie content.
   - Dose rate.

– Packaging equipment requirements.

5.7.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

3. EPRI. Waste Logic™ software programs and user manuals.

4. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

5. EPRI. "Filter Demineralizer Performance Improvement Program", 1996.

6. EPRI. "Proceedings; Second Workshop on Condensate Polishing with Powdered Resin", 1991.

7. EPRI. TR-109444, "Analysis of Advanced Liquid Waste Minimization Techniques at a PWR: Advanced Media, Pleated Filters, and Economic Evaluation Tools", March 1998.

8. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

5.8 Program Element: Non Precoat Filters

5.8.1 Program Impact

Non-precoated filters require a detailed understanding of the septa and backwash management. Refer to the "Cross References" listing at the end of this section for more detailed guidance.

Precoat elements are used extensively in BWR stations for processing high quality, high activity equipment drain waste and low quality, low activity floor drain wastes. The majority of the waste generated using this method of liquid processing is media changed out due to high dP or ion exchange performance degradation.

For systems that are configured with a precoat filter/demineralizer followed by a deep bed demineralizer, the potential exists for changing the filter technology from precoated septa to non precoat elements. The use of this advanced technology has been successfully demonstrated and can result in a significant savings to the utility without compromising overall system performance. However, prior to implementation and to ensure continued satisfactory performance during operation, the following issues should be adequately addressed.

5.8.1.1 Selection and Loading Logic

Recent experience with non precoat elements in floor drain, equipment drain and condensate applications has produced a large volume of pertinent information. To date, the use of this technology in low quality process waste streams has resulted in less than desirable results. However, properly implemented applications in higher purity streams such as equipment drains and condensate have proven to be successful and cost effective.

Similar to cartridge filtration or precoat septa selection, a thorough knowledge of the liquid to be processed and the end use of the system effluent are critical elements of septa selection. The success of non precoat filtration is highly dependent on a careful evaluation of particle sizes and distribution. Additionally, this technology offers the opportunity to significantly increase the total filter surface area, resulting in a highly desirable flux reduction.

Manufacturer support during the waste stream analysis, septa design and initial operation can result in more successful implementation of this technology. This support is critical when determining construction material compatibility with the application, micron rating, and when performing the filter flux and backwash analysis.

5.8.1.2 Operation

Non precoat filters are very susceptible to failure when exposed to poor quality inputs (e.g., organics, particulate). Therefore, water management practices should be incorporated into processing strategies to minimize low quality inputs.

By design, non precoat filters are not ion exchangers and are therefore operated to a predetermined dP endpoint versus chemical breakthrough. The filter dP directly impacts the performance of the filter modifying its ability to effectively process the waste stream at the design flow rate. Industry experience indicates that the filters should not be operated to the design upper dP, but that a lower, more conservative value should be used. This technique improves the effectiveness of backwashes, and helps delay irreversible septa fouling, increasing its useful life.

Another unique aspect of non precoat filter operation is related to backwash waste processing. The lack of fiber or ion exchange media greatly reduces the solid waste volume, but has negatively impacted the rate and quality of solids separation in phase settling tanks. The use of extended settling periods or the addition of chemical flocculants or polymers has been used to enhance this process.

5.8.1.3 Septa Changeout

Based on limited experience with non precoat elements, the changeout criteria has been based on a clean dP upper limit. The waste septa radiation and activity levels vary by waste stream and unit resulting in variations in VR and disposal options. When handling waste septa, the use of remote or extension tooling similar to that recommended for precoat septa, cartridge or bag filters can be effective for maintaining associated personnel exposure ALARA.

5.8.1.4 Waste Packaging, Volume Reduction, and Disposal

Waste generated as a result of non precoat septa use can be volume reduced and disposed using options primarily governed by the septa activity and packaging limitations.

Additional factors influencing VR and disposal include:

- Plant structural and space constraints.
- Waste concentration averaging.
- Available plant VR equipment.
- Disposal availability (long and short term).
- Disposal price structuring.
- Vendor services available for use.

Waste septa density can be manipulated or its volume reduced through compaction, supercompaction, shredding, chopping, or incineration. The available options are based on septa activity, corresponding dose rates and materials of construction.

5.8.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

5.8.2.1 Selection and Loading Logic

> **<u>CAUTION</u>:** The station should carefully review UFSAR, Licensing documents and safe shutdown requirements prior to altering septa configurations to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

1. The waste stream characterization and filter analysis described previously in Sections 4.4 and 5.5 should be completed prior to filter specification. Actual plant experience with non precoat septa indicates that several critical issues must be addressed for successful performance. They are:
   - An accurate analysis of the particle size distribution and loading. The particle size rating of the filter must be smaller than that of the liquid stream to be processed. Particles equal in size to the filter pores can result in particles being "wedged" in the membrane structure. These particles may not be removed during backwash cycles.
   - Filter septa flow characteristics and flux.
     - Non-precoat elements generally are operated to a lower dP than precoated counterparts. The added surface area reduces the backwash energy per unit area and

the lower terminal dP precludes driving the removed particulates into the membrane surface. The added surface area of a pleated non-precoat element results in a much lower operating flux.

– Vessel nozzle size, and backwash pressure and flow profiles should be evaluated. The drain lines for backflushes must be adequately sized to permit a rapid depressurization of the vessel during backwashes. The membranes require a significant shock for efficient crud removal from the filter.

– Vessel flow and pressure characteristics should be evaluated to ensure adequate flow rates and system pressures can be maintained during normal operations.

2. Testing a pilot unit is recommended prior to installation to optimize filter performance.

5.8.2.2 Operation

1. Identify and analyze expected fluctuations in the process waste stream characteristics. As part of that evaluation consider the impact of inputs rerouted from other process systems as well as outage liquid waste generation and its associated influent quality degradation.

2. Establish methods to preclude influent quality variations or degradation to the extent practical through procedural controls, equipment line-up reconfiguration or the use of alternates to processing.

3. Trend filter dP to effectively monitor performance.

4. Monitor the filter dose rate buildup over filter life.

5. Increasing the time allotted for phase separation or enhancing the settling process through the use of chemical additives.

5.8.2.3 Septa Cleaning and Changeout

1. Developing a correlation between the dose rate on the external surface of filter vessels and actual non precoat septa activity levels. Use this data to develop limits for changeout to maintain exposure ALARA. The analysis should also reflect filter dP, septa changeout costs, VR, disposal and associated labor while remaining cost effective.

> **NOTE:** “Clean” filter differential pressure (dP) profiles should be established and not exceeded. Precoat, non precoat and minimum precoat filter/demineralizers are particularly susceptible to irreversible fouling that can result in elevated dose rates and increased personnel exposure.

2. Establish a conservative upper clean dP limit to be used as an evaluation point for septa cleaning or replacement.

5.8.2.4 Waste Packaging, Volume Reduction, and Disposal

> **CAUTION:** Ensure changes to packaging strategies remain in compliance with the PCP, and container C of C and procedures.

1. Evaluate all options for VR and disposal including shredding, chopping, compaction, and incineration.
2. Review site imposed activity restrictions relative to non precoat septa dose rate, VR and disposal. Where applicable, adjust operational limits to ensure disposal costs are minimized.
3. Similar to the impact on alternate wastes, analyze the site structural layout to ensure septa VR, packaging and transport preparation evolutions are optimized.
4. Consider holding waste containers for decay prior to shipment.
5. Analyze the disposal fee structure to define the most cost effective packaging density and activity. As part of that analysis include density and activity changes on transportation fees and packaging and disposal options.

   When evaluating packaging requirements, include the following:

   – Container material, size, cost.

   – Stabilization requirements.

   – Density impact.

   – Dose rate.

   – Curie content.

   – VR and packaging efficiency.

   – Packaging equipment requirements.

5.8.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. Waste Logic™ software programs and user manuals.
2. EPRI. TR-105859, “Cost Effective Liquid Processing Programs”, 1995.
3. EPRI. “Filter Demineralizer Performance Improvement Program”, 1996.
4. EPRI. “Proceedings; Second Workshop on Condensate Polishing with Powdered Resin”, 1991.
5. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant”, 1989.

6. EPRI. TR-109444, "Analysis of Advanced Liquid Waste Minimization Techniques at a PWR: Advanced Media, Pleated Filters, and Economic Evaluation Tools", March 1998.

5.9 Program Element: Carbon

5.9.1 Program Impact

Granular activated carbon (carbon) is used as an organic adsorbent for organic molecules and solvents. Carbon functions using an adsorption mechanism; it has a surface similar to a sponge and target matter adheres to the surface. Because of its physical structure (texture), a teaspoon of activated carbon has a very significant total surface area (approximately equal to a football field).

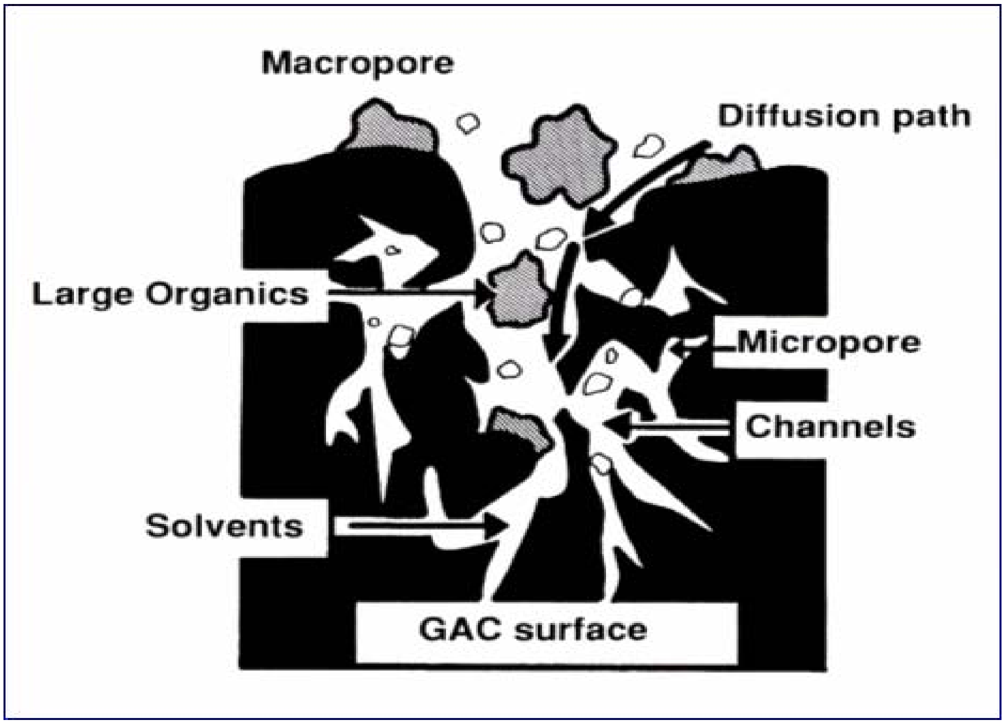

Figure 5-8
Granulated Activated Carbon Adsorption Schematic
Source: Environmental Analytical Systems

Historically, activated carbon media has primarily been used for LRW system prefiltration in pressurized water reactors (PWR). This treatment continues to be effective for organics and solids removal, providing protection for follow-on demineralizers and advanced filtration technology. In some applications, the use of copolymers has enhanced the applicability of carbon for cobalt and other specific isotope removal. This typically results in more rapid carbon loading, which is indicative of a successful process. In most LRW applications this results in generation of a low activity, Class A waste.

Several vessel designs incorporate a high energy backwash or top sluice feature. This technique results in a slurry requiring phase separation and decant, potentially introducing a volume of concentrated chemical and solid impurities into the radwaste processing system.

5.9.1.1 Selection and Loading Logic

Activated granular carbon is graded by mesh size. Selection of the appropriate mesh size is highly dependent on the characteristics of the influent waste stream and downstream processes. The material can be effectively used as depth filtration by layering the bed with various mesh sizes, such as a coarse-fine-coarse configuration. Fine carbon is typically 12-20 mesh, medium is 30-50 mesh and greater than 50 mesh is considered coarse. Layering is intended to extend the media throughput and more effectively remove various particle sizes using a single vessel. Another consideration in selecting mesh size is that the finer the mesh, the more difficult it is to sluice from the vessel. Pre-rinsed, acid-washed, coconut-based media has been used most often by the industry. Upstream pretreatment strategies including coarse cartridge based filtration and/or chemical pretreatment, will impact the overall process results.

The media selection analysis should also consider handling, packaging and disposition of the resultant solid waste. Equally important in the selection analysis is the vessel design, location and shielding to support normal operations and maintenance.

5.9.1.2 Operation

When used in a lead filtration mode, carbon performance will degrade with throughput; primarily as a result of particulate loading and biogrowth. There are four options for restoring performance:

1. High-energy, air-assisted backwash.

> **INDUSTRY EXPERIENCE**: Many stations use air assisted backwash to more thoroughly agitate the surface crud layer and to aggressively “scour” the bathtub ring from the vessel walls that is created by solids accumulating in the low flow perimeter.

2. Top sweep – crud removal, minimal carbon removal.

3. Top sluicing with the option to reload several cubic feet of media.

4. Total bed sluice and reload.

> **CAUTION:** Vessels with carbon media layered by mesh size should not be backwashed. This process can result in elimination of layers, creating a more homogenous mixture.

Some vessel designs are not conducive to top sweeping or sluicing, and a high-energy backwash will result in a waste stream with a high concentration of solids requiring additional treatment.

> **CAUTION:** Operating a carbon bed at a high dP can result in a compressed bed and lead to less than desirable backwash and sluice operations.

This waste stream (a significant source of biogassing nutrients) can be routed to a HIC containing waste ion exchange or carbon media to permit phase separation and decant of a higher quality liquid stream for normal radwaste processing methods. Top sluicing the vessel generates a slurry that is sluiced to a disposal liner for normal solid waste processing. This technique results in removal of the highest particulate waste concentration present in the processing vessel, restoring performance to near normal values, and generates minimal solid waste

Experience has shown that the backwash and top sluice are most effective if the vessels are not loaded to maximum design capacity. Instead, they are "short" loaded leaving sufficient space at the top of the vessel to accommodate adequate agitation to effectively remove the solids and/or media during the evolution. Pre-charge testing to verify expected performance or a pre-operational rinse to remove carbon fines generated during shipping and loading can alleviate concerns related to fines forwarding to follow-on beds. An effluent sample prior to placing the media in service can be used to verify media quality.

The considerations for backwashing the vessel are similar to filter/demineralizer septa. The backwash is most effective if the vessel is shocked by a high energy wash and rapidly depressurized, maximizing internal agitation of the waste solids and carbon media.

5.9.1.3 Changeout

Carbon vessels are typically operated to a predetermined dP endpoint, minimum flow rate, activity, or DF. At that time, the vessel is backwashed, top sluiced or a full changeout is performed to re-establish the desired performance.

Many factors influence the course of action selected including the following:

- Vessel design and inclusion of backwash or top sluice capabilities.
- Media type and period of service.
- "Clean" dP - the ability to adequately restore performance without changeout.
- Carbon loading strategy.
- Downstream processes.
- Desired performance (i.e., recycle versus release)
- Waste disposal options and costs.
- Outage planning considerations.
- Waste classification versus changeout criteria.

- ALARA considerations.

Any of the four performance restoration options will result in generating a low quality, potentially higher activity waste stream that requires additional treatment prior to recycle or release. The waste solids are normally transferred directly to a transportation liner for shipment to VR facilities or directly for disposal.

NOTE: High concentrations of polymers, lubricants and other chemical additives in the vessel can result in difficult to sluice media.

Vertical, top to bottom dose rate profiles taken on the outside surfaces of the vessel are effective for confirming that the vessel has been successfully emptied and rinsed. Dose rates above background may be indicative of residual media and/or solids. If dose rate does not go below a plant determined threshold, then the vessel should be opened and inspected.

Following removal of the spent media, an inspection may be warranted to assess the materiel condition of the vessel internals to ensure residual solids are not adhering to the inside walls of the vessel or remaining as a heel in the vessel. This is particularly important for plant using copolymers, carbon, or zeolite media. Inspections can be accomplished using miniature viewing equipment (e.g, boroscopes, video cameras) or via installed inspection ports.

5.9.1.4 Waste Packaging, Volume Reduction, and Disposal

Carbon waste is normally packaged in liners or HICs and either volume reduced through pyrolysis or directly disposed. Similar to other waste streams, the primary factor for determining immediate disposition is typically the waste activity. Carbon may be volume reduced using pyrolysis; however, variations in current disposal price structures or storage requirements can impact the cost effectiveness of this process. In addition, the VR for carbon is less than that for resin. Fine and Extra fine carbon tend to pass through the thermal VR system rapidly, further decreasing the attainable VR.

Sheet membranes, a bottom layer of low-activity resin, or HIC's with Powdex laterals have proven to be effective for de-watering carbon. These options help to minimize the transfer of carbon fines back to the plant/LRW system during liner decant. Decant from containers of RW (and other) media is typically low quality liquid with a high concentration of impurities. In the majority of stations, that liquid is routed back to the LRW system, immediately challenging the "new" media that replaced the packaged media. Under these circumstances, leaving as much of that liquid in the waste container as possible for shipment to off-site VR processes will result in reduced on-site decant processing and subsequently reductions in spent media generation and the associated costs and personnel exposure.

CAUTION: It is imperative that this practice and individual shipments are evaluated to verify compliance with:
- the shipping cask C of C
- shipping regulations
- vendor receipt criteria
- HIC/liner free standing water limits during movement (lifting)
- plant licensing documents and procedures
- on site staging/storage facility container free standing water limits

A 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

INDUSTRY EXPERIENCE: One station was required to stage filled liners in the site low level waste storage facility to accommodate shipping cask loading. That facility's UFSAR required all waste packages in that building to be dewatered to disposal site criteria, eliminating the previously discussed option.

5.9.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

5.9.2.1 Selection and Loading Logic

1. Carefully analyze influent characteristics and anticipated perturbations in accordance with the previous sections.

2. Obtain supplemental technical support from the product manufacturer for guidance related to optimum media type and loading configuration. Data gained during the waste stream characterization should be incorporated into this evaluation.

3. Use a primary 100% poly based or backwashing filter in front of carbon vessels if you have waste tanks with a high level of insoluble impurities that cannot be cleaned.

4. Identify required internal and external vessel hardware to accommodate top sweeping, backwashes, top and bottom sluice operations, and also the appropriate site interfaces to support those evolutions. The vessel should be designed for the "range" of carbon mesh sizes to be used to prevent fouling internal retention laterals.

5. The vessel design should include internal air sparging and water rinse capabilities and be adequately constructed to minimize the potential for premature failure of internal hardware as a result of high energy backwash and sluice operations or microbiologically induced corrosion (MIC).

6. When evaluating the vessel location consider:
   - Valving.
   - Instrumentation.
   - Hoses.
   - Personnel access for operation and maintenance.
   - Shielding.
7. Perform a media rinse prior to loading to remove fines generated as a result of shipping and on-site handling. A second, less desirable option is to perform the rinse following media loading, prior to service.
8. If using more than one carbon vessel, a layered carbon lag bed is recommended. Coarse grade carbon should normally be loaded on the top of the charge and at least medium grade media used on the bottom. The coarse carbon will minimize premature fouling of the fine carbon and the medium to coarse carbon on the bottom will preclude fouling effluent retention elements. Note: Backwashing layered carbon beds is not recommended.
9. The vessel should be short loaded (to less than the recommended maximum media charge volume) to ensure agitation during backwash and sluice operations is adequate. Additionally, a full charge may not be required for the system operational characteristics such as flow rate, retention time, etc.
10. Use scaled-down processing columns for testing media types and configurations prior to full scale implementation. This test equipment could also be used for future evaluation of proposed system processing improvements.
11. Ensure that as built vessel dimensions are carefully defined PRIOR to using that information for layout, operation, or other related evaluations. Frequently plant drawings do not accurately reflect as built data.

5.9.2.2 Operation

CAUTION 1: The station should carefully review UFSAR, Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

CAUTION 2: When practical, installed plant resin vessels designated for carbon should not be loaded with carbon media on the bottom. This may result in fouling retention laterals. A short charge of bead resin can be used to act as an interface between the carbon and laterals, minimizing fouling. In some cases this practice may also improve the performance for vessels specifically designed for carbon media.

1. Perform a pre-service rinse and analysis to verify media quality prior to use. This simple evolution can provide an additional protective measure for downstream demineralizers.

2. Similar to ion exchangers, the DF across the vessel should be determined and evaluated on a routine basis.

3. Routinely monitor vessel dose rate profile to determine activity loading as a function of vessel height.

4. Routine analysis of carbon bed influent and effluent for:
   - pH – organic media
   - Conductivity – organic media.
   - TOC.
   - Activity.

   The sample analysis types may vary dependent on recycle or release process operations. The analyses results should be reviewed as soon as possible to evaluate processing performance.

5. The suggested sample frequency is outlined as follows:
   - **System influent** - prior to process system startup, facilitating appropriate configuration changes based on identified impurities.
   - **System effluent** - as soon as possible following at least one system volume turnover. Maximum within one hour of process startup to verify satisfactory performance.
   - **Individual component or vessel performance** - weekly or as appropriate based on overall system performance and influent quality.
   - **Following any known system or influent transients** - influent and effluent samples - immediately.

6. Vessels with carbon media layered by mesh size should not be backwashed. This process can result in elimination of layers, creating a more homogenous mixture.

5.9.2.3 Changeout

1. Incorporating a top sluice capability in retrofit vessel design specifications, or when modifying existing vessels, to permit removal and replacement of media.

2. The backwash waste slurry should be treated as a separate waste stream either in a designated liner containing waste resin or carbon media, or in a retention tank that can be effectively decanted and desludged. Introduction of backwash waste to a normal liquid waste processing configuration would result in a severe challenge to processing media and components generating additional solid waste.

3. Verifying through radiation surveys or visual inspections that top sluice, backwash, or total bed sluices are effective and that minimal residual solids remain on vessel interior surfaces. If dose rate does not go below a plant determined threshold, then the vessel inspection may be warranted.

4. Internal vessel inspections may be prudent when copolymers are used as a liquid waste stream pretreatment strategy.

5. Inspections can be accomplished using miniature viewing equipment (e.g, boroscopes, video cameras) or via installed inspection ports.

6. Rinsing, sparging or opening access ports for manual high pressure cleaning following these evolutions can effectively reduce the immediate challenge to replacement media.

5.9.2.4 Waste Packaging, Volume Reduction, and Disposal

> **CAUTION 1:** Ensure changes to packaging strategies remain in compliance with the PCP, and container C of C and procedures.

> **CAUTION 2:** The bottom dewatering laterals on resin liners can be dependent on capillary action. To ensure compliance with disposal site residual liquid criteria, it may be prudent to load a bead resin bottom layer first, acting as a buffer to preclude clogging the dewatering laterals with carbon fines and other solids.

1. Similar to the impact on alternate wastes; analyze the site structural layout to ensure carbon VR, packaging and transport preparation evolutions are optimized.

2. Analyze the disposal fee structure to define the most cost effective packaging density and activity. As part of that analysis include density and activity changes on transportation fees and packaging and disposal options.

3. When evaluating packaging requirements, include the following:
   - Container material, size, cost.
   - Density impact.
   - Re-usable containers for off-site treatment

- Dose rate.
- Curie content.
- VR and packaging efficiency.
- Packaging equipment requirements.

5.9.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. "Preventing Biogassing in Low Level Waste", TR-111019, 1998.

3. EPRI. TR-105901, "Spent Resin Disposition-Available Alternatives and Selection Analysis", 1995.

5.10 Program Element: Ion Exchangers

5.10.1 Program Impact

Deep bed ion exchangers and several new technologies are designed for efficiently removing ionic impurities, and in some cases insoluble metals (corrosion products). Industry media management experience coupled with advanced media options, have resulted in significant reductions in generated waste resin volumes. However, effluent quality standards and spent media volume reduction and disposal are all dynamic in nature, mandating continued diligence when managing ion exchange programs.

Deep bed ion exchangers

Deep bed ion exchange resins remove insoluble products both by mechanical filtration and electrostatic attraction. Filtration is accomplished by trapping particulates in "pinch points" located between the resin beads. Smaller resin particle sizes will increase the number of those points (filtration efficiency) at a cost of increased dP. Bead resin can also act as a depth filter. Diligent oversight and operation of ion exchangers will mitigate the potential for the media to slough impurities to the system effluent, improving the success of liquid release or recycle efforts.

Ion Exchange Impregnated Filtration Media

Refer to the Single Use Cartridge and Bag filter section of this document for additional information regarding this technology.

5.10.1.1 Selection, Blending and Loading Logic

> **CAUTION:** The station should carefully review UFSAR and Licensing documents prior to using alternate media loading strategies to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

There are two types of whole bead ion exchange resins typically used for LRW demineralizers, strong acid cation and strong base anion resins. Deep bed resins are typically styrene divinylbenzene (SDVB) copolymers. These resins are given the name "gel-type." The degree of divinylbenzene crosslinkage gives the resin properties of strength and stability (resistance to oxidation), as well as increased functional group density. Macroporous ion exchange media is rapidly becoming accepted as an improved method for balance of plant processes. This media warrants consideration as part of the selection evaluation process; however, the specific LRW application and resultant waste handling should be carefully evaluated for process efficiency, performance, and cost.

Ion exchange resin is organic in construction. Therefore, as oxidation of resin occurs, organic impurities can be introduced to the system if the anion resin doesn't remove it. For process and release, this is probably an insignificant issue.

However, for reactor water recycle applications, resin fines are broken down to carbon dioxide, weak organic acids, and the acid or base form of the functional groups in the reactor because of neutron flux and temperature.

Ion exchange resin design performance is predicated by system inlet characteristics. As such, the waste stream characteristics and fluctuations impact the resin's performance. The expense associated with more costly custom or advanced media applications, should be commensurate with the desired effluent results.

Mixed bed resin from suppliers should be used only if it is within the shelf life specified by the manufacturer. Consideration should be given to its performance based on fines generation, or use in recycle applications.

> **INDUSTRY EXPERIENCE:** Plants use high-crosslinked cation resin for increased capacity and ionic selectivity; however, it may lead to higher dose rates.

The stoichiometric mix, or ratio of anion to cation resin in a mixed bed, can directly impact the generated volume of solid radwaste. The stoichiometric mix used should be based on the relative concentration of anion and cation impurities to be removed from the influent waste stream. An improper mix can result in anion depletion prior to cation depletion (particularly true for atmospheric or aerated systems), or vice-versa. Traditionally, a 60-40 anion to cation ratio has been used. Through experience, many plants utilizing mixed beds have modified the ratio to closer to a 40-60 anion-to-cation blend. For some radwaste applications, this results in a higher media throughput prior to chemical or radioisotope break.

For plants that use a chemically equivalent (stoichiometric) mix of anion and cation media, the resins must be properly sized in order to prevent separation during transfers and/or vessel fills. If the resin separates, it is difficult to achieve desired effluent water quality.

If the liquid treated is to be recycled, a mixed bed is selected. These beds must provide water purification and remove nuclides. Break through of chloride, fluoride, sulfate, nuclides, silica and pH are criteria for changeout of mixed beds.

If the liquid treated is to be discharged, ion exchange selection can be based solely upon the removal of radionuclides. By removing only radionuclides spent media generation can be reduced without adversely impacting effluent activity. In general, cobalt, nickel, iron, cesium, iodine and antimony are prominent nuclides in effluent. Antimony has a low effluent dose impact when compared to other nuclides.

Organic cation resin will remove soluble species of cobalt, nickel, iron and cesium. Historically, hydrogen form cation resin has been used for this service. Sodium form cation resin in concert with influent pH adjustment has demonstrated increased throughputs.

Cesium will generally be the first soluble nuclide to break through an organic cation bed. Cesium is a nuclide with a high effluent dose impact. If cation resin throughput is limited by cesium break, the use of cesium selective media should be considered.

Inorganic zeolites (e.g., chabazyte, clinoptilolyte) have been shown to be highly selective in removing cesium from liquids with conductivities less than 2,000 µmho/cm. These materials have demonstrated a higher capacity for selective ion removal. Zeolites have been used for LRW treatment by both spiking organic beds with a few cubic feet of material and by separate beds containing only zeolite. If a separate zeolite bed is used, it should be aligned upstream of the cation bed so that the cation resin will not become Class B because of Cs-137. Synthetic and natural zeolites have demonstrated improved throughput when compared to organic resins.

Many other cesium selective media are available. They are all inorganic, and their use should be considered for influent liquids with conductivities higher than zeolites are capable of effectively treating.

CAUTION 1: The corrosion impact of a heavy inorganic media on the spent media transfer piping must be considered prior to use.

CAUTION 2: The ability to package the spent inorganic media in compliance with disposal site criteria and HIC C of C's commingled with resin and/or carbon must also be evaluated prior to use.

Organic anion resin is very selective for iodine removal. Anion resin will also remove some forms of soluble cobalt. Antimony is removed by anion resin, but has a low affinity for it. Shifts in influent pH can release antimony collected on an anion bed. Anion resin has a higher affinity for boron than antimony. In borated liquid processing scenarios, the demineralizer effluent antimony may exceed the influent.

For plants with only one deep bed vessel processing for discharge, a mixed bed should be used. Altering the cation to anion ratio can extend the life of such mixed beds. Cation to anion rations of 4:1 up to 9:1 have been reported to provide suitable effluent and increased bed life. Altered cation to anion ratios equate to predicting the ionic nuclide makeup of influent liquids. The consistency of influent liquids will dictate the extent and the success of altered resin ratios.

Segregated ion exchange beds with a different media in each bed has been adopted by many plants processing for discharge. By separating the media into different vessels, each media type can be used to depletion. No media must be disposed of prematurely because of the exhaustion of other media in the same vessel. By separating the media into different vessels, predicting the makeup of influent liquid is not as critical.

INDUSTRY EXPERIENCE: At least one station leaves a "spare" ion exchange vessel empty. This vessel is used to accommodate media that is selected and loaded to meet unanticipated influent waste stream challenges.

Occasions exist when it may be desirable to short-load a resin bed to minimize the solid radwaste generation. However, prior to short-loading the bed, the following considerations should be evaluated:

- UFSAR and/or design basis document—Including post-accident processing requirements (if applicable).
- Influent contaminants and their exchange zones in the resin bed.

Several stations have opted for the use of a carbon overlay that is intended to provide protection to the underlying ion exchange media by removing organics and filtering solids. The quality of the overlay application is difficult to validate due to hydraulic separation during loading. Additionally, following spent media sluice to waste containers, the carbon content may result in challenges to the dewatering process (refer to Carbon section of this document for additional dewatering detail).

Macroporous resins can result in improved solids removal. However, the media typically has a low crush strength (friability is high). Therefore the media requires careful handling during transfers to preclude damaging the resin and creating undesirable levels of resin fines.

5.10.1.2 Operation

The primary objective of demineralizer operation is to achieve the desired effluent quality with minimal radwaste generation in a cost effective manner. In order to attain these goals, the operator must have a thorough understanding of the media, demineralizer system, and its operation.

Waste stream characteristic stabilization can aid in achieving this goal. The treated waste stream characteristics and potential fluctuations can dramatically impact media performance. Low quality influent can rapidly foul, or deplete ion exchange media. Resin that is improperly loaded, rinsed or "fluffed" can result in fractured beads, effluent chemistry fluctuations and destruction of chromatographic bands. These deviations all negatively impact media performance.

Some stations have the ability to align demineralizers in various series and parallel configurations. This allows the operator to establish custom line-ups, tailoring the process to accommodate influent LRW characteristics and to achieve the desired effluent quality. The fundamental industry standard for purification system logic employs a cation bed followed by an anion and mixed-bed.

INDUSTRY EXPERIENCE: At several stations, partially depleted condensate polisher or SGBD processing media is transferred to the radwaste system deep bed for further ion exchange utilization. This practice has the benefit of using a majority of the resin capacity. Normally, individual vessel and system dP is monitored to evaluate solids loading, influent characterization changes and prefiltration adequacy. This option should be weighed against the increased media activity and the subsequent impact on cost, VR, and disposal options. This option also has the potential to generate low quality (high iron) sluice waste water, and in some scenarios impacts personnel exposure.

Using the isotopic composition of the influent LRW or historical spent media data, and the media type in service, a correlation can be developed between the dose rate on the vessel external and the approximate media curie content and dose rate. This is useful when establishing activity limitations related to volume reduction options, personnel exposure and disposal costs.

Anion resin tends to become fouled with organics from cation resin breakdown (de-crosslinking/oxidation), hydraulic fluids and iron. Anion resin is more susceptible to kinetic impairment than cation resin. When resin kinetics are lost, the resin will lose its salt-splitting capacity and anions will pass through to the LRW system effluent.

Strong acid cation resin has a maximum operating temperature limitation of 250 °F, but typical limits are 140 °F because of high sulfate releases. Strong base anion resin has an upper temperature limit of 140 °F. High temperatures cause the quaternary ammonium functional group to convert to the tertiary amine group (or become weak base), losing salt splitting capacity.

5.10.1.3 Changeout

Domestic plants use data such as dP limitations, media activity, chemistry/activity breakthrough, or total processing throughput to develop changeout criteria.

Increasing the throughput may result in an increase in resin activity and therefore waste classification. Defining changeout criteria (i.e., dP, throughput, DF, activity, dose) requires careful analysis of the desired effluent for individual beds. It also requires an analysis of the costs associated with spent resin packaging, transport, VR and disposal. The incorporation of

ALARA considerations related to system operation, and changeout planning and scheduling is prudent.

INDUSTRY EXPERIENCE: Several stations rotate bed alignment, moving the trailing (effluent) bed to the front to act in a filtration and protection mode. This is typically based on the concentration of a specific isotope in the trailing bed's effluent. At least one station uses Antimony as the indicator, realigning vessels when the effluent Antimony is in the 1 E-5 to 1 E-4 range.

CAUTION: This method should be carefully evaluated and monitored if employed in effluent recycle applications to prevent undesirable effluent performance because of pH swings and/or impurity or activity sloughing.

However, restrictive limitations may be offset by increased resin procurement and disposal costs.

INDUSTRY EXPERIENCE: Several stations have determined that more frequent media changeout in an effort to minimize personnel exposure, has actually resulted in increased exposure related to the more frequent packaging and disposal operations.

When performing a resin sluice/transfer, shielded transfer lines and high energy post transfer line flushing will minimize personnel exposure. Maintaining an optimal spent resin to water ratio will result in a fluid slurry and will help to ensure transfer lines do not clog. This eliminates additional effort that could result in increased personnel exposure and liquid waste volumes.

Macroporous resins typically has a low crush strength (friability is high). Therefore the media requires careful handling during transfers to preclude damaging the resin and creating undesirable levels of resin fines.

Segregated temporary holdup (spent media tanks) or packaging options (direct to waste packages) allow for selecting cost effective packaging, transport, volume reduction, and disposal options. The ability to sluice spent media directly to waste containers, by-passing in plant tanks, also eliminates generation of a second volume of sluice water. That in turn reduces the challenge to plant processing media and minimizes the potential for creating sluice related hot spots or other sluice related problems.

5.10.1.4 Waste Packaging, Volume Reduction, and Disposal

Waste bead resin is typically packaged in liners, HICs, or re-usable waste containers and either volume reduced through thermal destruction or directly disposed in shallow burial landfills. The residue from thermal destruction can also be used as overfill for other solid waste containers to optimize the packaging efficiency, waste density, or activity. Dependent on waste stabilization requirements, resins can be encapsulated in advanced polymers or solidified using a cement-based agent. Similar to other waste streams, the primary factor for determining disposition is the waste activity. Low activity resin can be thermally destroyed, or for very low activity resins, disposed using direct on-land disposal at an authorized (Title 49 Industrial) landfill site.

Higher activity wastes can be treated using pyrolysis or direct disposal. Direct disposed resins are packaged and dewatered to meet transportation regulations and disposal site criteria and can be encapsulated/solidified as referenced previously.

Shipping for pyrolysis may or may not require dewatering prior to shipment. Decant from containers of RW (and other) media is typically low quality liquid with a high concentration of impurities. In the majority of stations, that liquid is routed back to the LRW system, immediately challenging the "new" media that replaced the packaged media. Under these circumstances, leaving as much of that liquid in the waste container as possible for shipment to off-site VR processes will result in reduced on-site decant processing and subsequently reductions in spent media generation and the associated costs and personnel exposure.

> **CAUTION:** It is imperative that this practice and individual shipments are evaluated to verify compliance with:
> - the shipping cask C of C
> - shipping regulations
> - vendor receipt criteria
> - HIC/liner free standing water limits during movement (lifting)
> - plant licensing documents and procedures
> - on site staging/storage facility container free standing water limits
>
> A 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

Historically, the primary drivers for selecting a disposition option are disposal site criteria and cost structure. Additionally, spent resin packaging, VR and disposition options are impacted by:

- Plant structural and space constraints.
- Waste resin blending and concentration averaging.
- Resin treatment options – on and off site
- Dewatering equipment.
- Disposal availability (long and short term).
- On-site storage requirements
- Plant license documents including the UFSAR, Technical Specifications, PCP and shipping cask C of C.

5.10.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

5.10.2.1 Design, Selection, Blending and Loading Logic

1. Evaluate all goals that impact resin selection and change-out criteria. Include the following in the analysis:
   - Personnel exposure
   - Resin procurement
   - Throughput
   - Waste packaging and disposal classification.
   - Outage planning considerations.
2. Develop resin selection and loading plans based on known plant evolutions. Document the criteria used for future reference.
3. Radioactive ion exchange media selection for recycle.
   - Determine the reason for mixed bed replacement. Is cation capacity depletion the cause for bed replacement or anion capacity? Does the reason for replacement change from one bed to the next?
   - If the cause for bed replacement is consistent, consider altering the ratio of cation to anion as appropriate.
   - Consider an alternate supplier of mixed bed resin. Organic resin from one vendor may have higher capacity for soluble species than what is currently in use.
4. Radioactive ion exchange media selection for release.
   - If only a single vessel is available, consider changing the cation to anion ratio to increase bed throughput.
   - Determine if cation throughput and performance is acceptable. If it is not, consider the use of an alternate, isotope specific media for processing low conductivity inputs.
   - If influent conductivity is high and cesium effluent is a concern, consider the use of inorganic cesium selective media.
   - If multiple vessels are available, consider segregated loading of ion exchange media to preclude premature media depletion. As part of that evaluation, consider release permit requirements, cost effectiveness and the impact on operator attention.
   - Evaluate the use of isotope specific media to resolve plant-specific issues.
   - Evaluate using high cross-linked, high capacity cation resin.

CAUTION: Prior to using partially depleted low activity media from other plant systems, the station should evaluate the cost factors including:

- The remaining capacity versus disposal as low activity resin.
- Disposal costs for depleted resin following activity increase associated with LRW processing.
- New resin procurement and warehousing.
- Labor, containers and storage of partially depleted media waiting LRW use.
- Solids/particulate loading (iron) of the re-used resin.

5. For re-use of non-radioactive resin in radwaste systems, consider partially depleted condensate polishing or SGBD resin for LRW processing.

6. Ensure the procurement specification stipulates sifting for particle size and that organic chemicals are fully rinsed from the resin. Establish a manufacturer's limit for the percentage of acceptable fines. There have been instances where resin impurities and fines have caused reactor coolant chemistry excursions.

7. Following process stream characterization, develop separate detailed specifications for each resin application. Ensure that the resin type/blend is commensurate with the intended function. The waste stream characterization, processing system goals, and process flow rate should be used to select a resin for the desired performance. Avoid the use of a single generic media design for different waste streams for the sole purpose of streamlining the procurement and on-site warehousing process.

8. Anticipated waste stream characteristic fluctuations should be considered when specifying resin. Known fluctuations or expected perturbations based on planned and projected plant evolutions should be analyzed for impact on media performance.

9. Evaluate the resin procurement and disposal cost versus application in the system. Utilize custom blend or isotope specific media only when it is cost effective or required to meet release criteria. Use "off the shelf" media whenever possible to minimize processing costs.

10. Consider an alternate supplier of resin. Organic resin from one vendor may have a higher capacity for soluble species than what is currently in use.

11. For mixed beds, minimize water volume in vessels during resin loading to prevent hydraulic separation.

12. Procedures and operational practices for layering carbon with ion exchange media should be evaluated to ensure the differing media densities are taken into account when charging vessels. Differing medias in a fully immersed bed may separate due to density differences altering the desired end result. Additionally, backwashing layered beds to remove or redistribute solids deposits, will disrupt the layers as well as the resin chromatographic bands, negatively impacting the process. Finally, it is likely that the carbon life cycle will exceed that of the resin, therefore an unintentional mixed carbon/resin bed will require complete sluicing generating unnecessary carbon waste.

13. When specifying replacement or add-on demineralizer vessels, the specifications should address minimization of MIC, include a specific rinse header, flow distribution plate/baffles and retention screens sized for the specific media application.

14. Ensure that as-built vessel dimensions are carefully defined PRIOR to using that information for layout, operation, or other related evaluations. Frequently plant drawings do not accurately reflect as built data.

15. Ideally, site batched mixed bed resin should be used immediately following mixing. If the cation resin to be used exceeds the shelf life, it should be rinsed separately to remove leachable organics prior to mixing with anion resin.

16. If resins are not used within the vendor recommended shelf life, each resin lot should be sampled for capacity and leachable organic concentration.

17. Evaluate the effectiveness of "short" loading vessels. Include the following in that evaluation:
    - System flow rate and residence time.
    - Channeling potential.
    - Regulatory and design requirements.
    - UFSAR and/or design basis document—Including post-accident processing requirements (if applicable).
    - Influent contaminants and their exchange zones in the resin bed.

18. Ensure the resin selection process results in a media that is compatible with planned waste volume reduction, disposal, or storage options and criteria. As part of that evaluation consider:
    - Friability (crush strength) of resin and associated handling cautions—Macroporous resins typically has a low crush strength (friability is high). Therefore the media requires careful handling during transfers to preclude damaging the resin and creating undesirable levels of resin fines.
    - Expected resin capacity and activity buildup
    - Plant design relative to generated waste segregation capabilities
    - Planned reduction in Class BC waste due to disposal site restrictions for those wastes
        - Cation to anion ratio relative to total bed activity
        - More frequent changeout
    - Use of thermal VR treatment – material and activity compatibility
    - Package compatibility
    - Long term storage resistance to radiolytical decomposition

5.10.2.2 Operation

CAUTION 1: The station should carefully review UFSAR, Licensing documents and release permits prior to using process alternatives to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

1. Perform a pre-service rinse and analysis to verify media quality prior to use. This simple evolution can provide an additional protective measure for downstream demineralizers.
2. Determine and evaluate the DF across each ion exchange vessel on a routine basis.
3. Routinely monitor vessel dose rate profile to determine activity loading as a function of vessel height.
4. Routine analysis of demineralizer influent and effluent for:
   - pH – organic media.
   - Conductivity – organic media.
   - TOC.
   - Activity.

   The sample analysis types may vary dependent on recycle or release process operations. The analyses results should be reviewed as soon as possible and trended to evaluate processing performance.
5. The suggested sample frequency is outlined as follows:
   - **System influent** - prior to process system startup, facilitating appropriate configuration changes based on identified impurities.
   - **System effluent** - as soon as possible following at least one system volume turnover. Maximum within one hour of process startup to verify satisfactory performance.
   - **Individual component or vessel performance** - weekly or as appropriate based on overall system performance and influent quality.
   - **Following any known system or influent transients** - influent and effluent samples - immediately.
6. In addition to sampling, routine Chemistry support should be established to evaluate system performance, media usage, system configuration and waste minimization.
7. Consider the use of finer micron laboratory filter paper as compared to standard 0.45µm filter paper for determining soluble effluent from LRW treatment units.

8. Establish media configuration and changeout criteria based on known inputs and historical data. Develop demineralizer dose rate based activity limitations to ensure waste disposal remains cost effective.

9. When processing for recycle, perform a pre-service rinse to minimize the transport of manufacture and handling contaminants to system effluent.

10. Use bed dP data obtained during operations to evaluate particulate loading and the efficiency of deep bed prefiltration.

11. Develop outage plans to effectively process waste streams with varying chemistry and activity characteristics. Consider leaving an empty vessel for emergency applications.

> **INDUSTRY EXPERIENCE:** _Several stations have successfully addressed outage wastes by developing specific outage guidance in their "Liquid Radwaste Processing and Water Management Guidelines" procedure. The guidance includes borated water segregation for recycle without processing and the interface between the Radwaste Control Room Operator and the Water Management Coordinator to ensure that the impact on, and impact resulting from, LRW processing is minimized.

12. Resins should not be backwashed/fluffed after they have been in service. The solids and ionic loading that were retained will be redistributed, potentially to the bottom of the vessel, and impurities may leak to the system effluent. The chromatographic ion gradient in the vessel will be disturbed and increased ionic leakage will be evident.

5.10.2.3 Changeout

1. Ensure the media to water ratio is optimized to fluidize the resin and prevent agglomeration and subsequent line clogging.

2. Prior to changeout, evaluate operational monitoring data perform an evaluation of demineralizer liquid effluent to verify results are because of decreased demineralizer capacity and not caused by influent perturbations (i.e., particulate activity versus soluble activity leakage).

3. Consider holding a bed for decay of short-lived isotopes prior to replacement. Multiple vessels must be available in the LRW system (e.g., three or more) to implement this practice.

4. Following bed transfer, perform a high energy backwash or vessel rinse to ensure residual fines and other solids (the bathtub ring) have been effectively removed prior to recharging the vessel with new media.

5. Route decant waste liquid to a storage tank or liner containing waste resin. The resin can act as a particulate filter and any residual ion exchange capacity can be effective at reducing effluent activity prior to routing to the waste collection tanks.

6. Stop HIC fill prior to being full and flush with demineralized water to prevent resin line "clogging."

7. Use installed and portable shielding and low traffic routing for lines/hoses when practical to minimize personnel exposure during spent resin sluice operations.

8. Perform an inspection of vessel internals on a routine basis to determine condition of internal components.

9. Establish slurry water input flow rates to maintain the spent resin in a desirable, transferable consistency (e.g., 7 ft/second at a consistent flow rate).

5.10.2.4 Waste Packaging, Volume Reduction, and Disposal

1. Evaluate all disposal and VR options. That analysis should consider:
   - Safety analysis (UFSAR and industrial)
   - Disposal site and VR vendor site location and associated transportation fees
   - Disposal site and VR vendor site access stability
   - Disposal site and VR vendor site acceptance criteria
   - Disposal site and VR vendor fee structure
   - The most cost effective packaging density and activity.
   - Container material, size, cost.
   - Density impact.
   - Dose rate.
   - Curie content.
   - VR and packaging efficiency.
   - Packaging equipment requirements.

2. Analyze the site structural layout to ensure resin packaging and transport preparation evolutions are optimized. As part of that evaluation consider alternate use of existing facilities, addition of simple, cost effective alterations, and removal of equipment "retired in place" for optimizing the use of alternate space.

> **CAUTION:** Ensure changes to packaging strategies remain in compliance with the PCP, and container C of C and procedures.

CAUTION: The bottom dewatering laterals on powdered resin liners can be dependent on capillary action. To ensure compliance with disposal site residual liquid criteria, it may be prudent to load a bead resin bottom layer first, acting as a buffer to preclude clogging the dewatering laterals.

3. Evaluate eliminating gross and final dewatering steps for media that is designated for thermal destruction.

CAUTION: It is imperative that each shipment is evaluated individually to ensure that this practice is in compliance with the shipping cask C of C, shipping regulations, vendor receipt criteria, and plant licensing documents and procedures. A 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

4. Evaluate increases in waste classification caused by VR AND/OR increased packaging efficiencies. Ensure the parallel increase in packaging and disposal costs is less than the cost associated with the originally higher volumes at a lower specific activity and waste classification.

5. Analyze spent resin packaging and VR practices to ensure that the increased packaging efficiency does not increase the specific activity of nuclides such as carbon-14, nickel-63, and TRU to levels that result in Greater Than Class C waste.

6. Evaluate the potential for organic contamination (e.g., low quality wastes from floor drain systems) and their impact on methane gas generation.

INDUSTRY EXPERIENCE: At least one station adds hydrogen peroxide to their low quality, low activity waste collection tanks prior to processing to maintain at least 2 ppm during processing. This eliminates the anaerobic bacteria thereby reducing the biological load on filters. During outages, at least 2 ppm of hydrazine is maintained (versus peroxide), in the collection tank to control colloidal iron species that would otherwise result in transport of Co-58 through the entire system; that hydrazine also appears to eliminate the anaerobic bacteria.

5.10.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

2. EPRI. “Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations”, 1993.
3. EPRI. Waste Logic™ software programs and user manuals.
4. EPRI. TR-105859, “Cost Effective Liquid Processing Programs”, 1995.
5. EPRI. “Preventing Biogassing in Low Level Waste”, TR-111019, 1998.
6. USNRC. Regulatory Guide. 1.56, "Maintenance of Water Quality in Boiling Water Reactors”, Revision 1, 1978.
7. EPRI. TR-105901, “Spent Resin Disposition-Available Alternatives and Selection Analysis”, 1995.
8. EPRI. NP-5099, “In-plant Testing of Radwaste Ion Exchange Materials”, 1987.
9. EPRI. TR-1008128, “Development of the EPRI Magnetic Molecules Technology”, October 2004.

5.11 Program Element: Evaporators

5.11.1 Program Impact

The majority of U.S. plants have retired their waste processing evaporators and replaced them with more reliable, less costly alternate technologies. Similar to and often intermingled with the term evaporator, a crystallizer is an evaporator that can handle 25-50 wt% solids. Several stations continue to successfully operate evaporators for both low conductivity, high activity RCS letdown recycle or waste and a few for LRW processing. The evaporators are typically designed to attain a ~15 gpm process flow rate.

A generic evaporator description follows:

The influent waste stream is collected in tanks then pumped to the evaporator package by the evaporator feed pumps. The package typically consists of an evaporator, absorption tower, evaporator condenser, eductor, concentrate pump, and distillate pump. The condensate produced flows through a demineralizer to a waste evaporator condensate tank and then to monitoring tanks.

Recycling liquid will result in the production of evaporator distillate (pure water) and the capture of boron for reuse, both resulting in potential cost savings. However, evaporator use can also result in concentrating silica, chlorides and other chemical impurities. These can pose a significant challenge to downstream demineralizers resulting in excessive media generation and can challenge chemical species limits in recycle tanks and the SFP. Additionally tritium is concentrated in the liquid stream and can result in elevated dose rates adjacent to the SFP and reactor cavity (during refueling operations). The increased tritium concentration also impacts the plant vent release activity levels due to evaporative losses originating from the SFP and plant leakage.

This section deals primarily with LRW processing; however, much of the information can be used for boron recycle evaporation processes. Evaporators for processing LRW typically result in a high quality, low activity effluent suitable for either release or recycle to reactor or condensate systems. Industry experience has shown that evaporation results in program attributes which include:

- High quality, low activity effluent.
- Relatively high maintenance costs

> **INDUSTRY EXPERIENCE:** In an effort to maintain evaporators in an operable condition, one station performed a major overhaul on one of three evaporators each fuel cycle. The estimated costs per overhaul including parts, labor, personnel exposure and waste disposition exceeded $500,000.

- Relatively high personnel exposure during maintenance and operation.
- Concentrates waste requiring final processing prior to disposal.

5.11.1.1 Use Issues

Evaporators can produce a high quality product; however, they typically require a significant amount of operator attention during operation. In process and recycle applications, there is a significant benefit to achieving this quality relative to reactor water chemistry and its consequences. At several stations, antimony is a major component of the total effluent activity. Evaporators are an effective method for antimony removal. For process and release applications, the benefit of efficient processing is often overshadowed by operating and maintenance considerations.

The need for prefiltration and pre-demineralization is dependent on the influent quality. An evaporator’s function is to effectively concentrate impurities including solids; however, excessive impurity loading can foul heat transfer surfaces or result in carryover to the effluent stream. This issue becomes more critical with system influent fluctuations related to system maintenance, refueling (cavity draindown), and other outage evolutions.

Frequently, the performance of LRW evaporators is affected by surfactants and organics generated during routine and outage housekeeping and decontamination campaigns. These inputs can cause foaming and/or heat transfer loss resulting in decreased effluent quality. The energy required to operate an evaporator and the attendant cost are also significant. Those requirements are also negatively impacted by evaporator influent quality perturbations.

Many stations have also determined that operating boron recovery evaporators is not cost effective when compared to demineralization and release, procuring replacement boron and makeup water. Additionally, boron has a “useful” life and is depleted over time, requiring replacement. Boron recycle also has the potential to concentrate undesirable impurities such as silica, requiring periodic process and release or alternate processes to reduce the concentrations to an acceptable level. However, the potential for increased boron costs associated with enriched boron as a reactivity control agent may make evaporation for recycle a cost effective operation.

INDUSTRY EXPERIENCE: One station processes RCS letdown using their recycle evaporator to 4wt% boric acid concentrates. The concentrates are then processed using a relatively small RO system to reject silica successfully removing that impurity.

5.11.1.2 Operation

As discussed previously, evaporation requires a significant amount of Operator attention to maintain high quality effluent. The temperature and pressure, critical to the operation must be closely monitored and regulated to:

- Maximize boiling.
- Minimize carryover.
- Maintain concentrates density (weight percent-wt. %) within the desirable control band.
- Minimize energy demands.

The goal is to maximize heat transfer at the lowest temperature and highest process rate. In a properly operated evaporator, pressure can be effectively used to optimize these parameters.

During outages, the demands on operators rise with increased influent volume and the increased potential for lower quality influent following crudburst and cavity cleanup. The quality is also adversely affected by an increased input of surfactants and organic cleaners related to outage cleanup evolutions. Furthermore, steam and cooling water maintenance during refueling outages can result in evaporator down time during periods when influent volumes are often at peak capacity.

5.11.1.3 Maintenance

Evaporator maintenance is typically a costly process. There are costs associated with labor, parts, warehousing fees, personnel exposure and waste disposal. The use of routine PM and major overhauls, has proven to be effective at maintaining some evaporators in there optimum condition. However, as evaporators age and manufacturers focus on alternate technologies, parts become less available or require costly custom manufacture.

Some stations routinely clean evaporators using a chemical process. The goal is to improve heat transfer by removing impurities “cooked” on heat transfer surfaces. However, this process results in a chemical waste that requires treatment and disposal.

During operation, LRW and boron recycle evaporators tend to create an acidic environment inside the evaporator's components. pH monitoring and control capabilities are critical to ensure optimal evaporator performance and to minimize damage to internal components. When replacing components on any evaporator, an analysis of materials of construction can result in improved specifications and enhanced performance related to heat transfer and corrosion.

5.11.1.4 Waste Packaging, Volume Reduction, and Disposal

Evaporator concentrates are typically dewatered and dried using thermal processes or solidified for disposal. While solidification is adequate for stabilization and methane gas minimization, it significantly increases the volume of waste requiring disposal. Thermal VR and packaging processes require additional on-site equipment and processes, or shipment of the slurry to off-site vendors for processing. LRW evaporator concentrates packaging and disposal options are primarily controlled by the activity and drying/VR processes. The following also impact process use and cost:

- Evaporator performance - wt. %.
- Plant structural and space constraints.
- Available plant drying/VR equipment.
- Available vendor services for on and off-site drying/VR.
- Liquid concentrates packaging and transport.
- Disposal pricing structure.
- Disposal availability (long and short term).

5.11.1.5 Exposure

As discussed previously, evaporator operation requires fairly close oversight and routine maintenance/overhauls. Evaporators also are not "rinsed" following use and activity buildup in components over time is typical, unless the evaporator feed filters and demineralizers are effective at removing the bulk activity. Concentrates handling operations related to transfer, drying/VR and packaging result in additional exposure. Evaporator chemical cleaning, while primarily intended to improve heat transfer coefficients can result in reduced dose rates for a period of time.

5.11.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

5.11.2.1 Use Issues

1. Calculate a cost for evaporator operations. This cost analysis should, at a minimum, include the following components:

- Electricity costs for operation of pumps, etc.
- Steam consumption for evaporator operation.
- Cooling water demands.
- Required spare parts inventory, warehousing and inventory taxes.
- Feed and polishing demineralizer's media procurement and depleted media disposal costs.
- Concentrates handling, drying/VR and disposal costs.
- Operations costs (use loaded labor rates that include benefits).
- Maintenance costs (include planning, labor and parts, annualize modification costs).
- Exposure related costs ($/person-Rem).
- Process rate in gpm.
- Boron recycle - boron and makeup water replacement costs.

2. Evaluate and if possible, eliminate or minimize the use of evaporator feed filtration and demineralization. Consider the use of larger micron ratings on feed filters, minimizing waste generation, if filtration is retained.

3. Similar to feed demineralization, evaluate the need versus benefit for polishing ion exchangers. Frequently the cost associated with media procurement and disposal off-set the benefit derived from improved effluent quality.

4. Use the cost analysis above, evaluate the use of alternate processes for primary system waste. Filter and demineralization and membrane processing can frequently be more cost effective, meeting recycle or release requirements.

5. Evaporator materials of construction should be evaluated prior to their initial use. Stainless steel construction is not recommended for low quality, high conductivity waste streams (e.g., floor drains with F^-, Cl^-). Alloys such as Inconel or Hastalloy are recommended for processing more aggressive waste streams. This guidance is also pertinent when considering "changing" the intended use of currently installed evaporators (e.g., using the recycle evaporator for LRW processing).

> **INDUSTRY EXPERIENCE:** _At least one station has reconfigured system line-ups to use installed evaporator demineralizers for routine processing without evaporation.

6. Provide operators with comprehensive training related to evaporator operation. As part of that training, include information related to concentrates disposal costs and evaporator effluent impact on reactor/condensate chemistry or plant liquid effluent activity.

7. Consider maintaining a dedicated crew of evaporator operators to maintain a high level of proficiency and to consistently achieve high quality performance results.

8. Develop plans for influent deviations. Evaporator operators can frequently provide valuable historical experience related to input's impact on performance - their input should be solicited to enhance the plan's success.

> **INDUSTRY EXPERIENCE**: Borate solubility is dependent on temperature and pH of a solution. The highest solubility of borates occurs at 77ºF in pH value = 7.0. One plant corrects the pH in the collecting tanks between 7.0 and 8.0 in order to obtain a pH of ~7.0 in the evaporator bottoms. As a result, the plant was able to achieve concentrations of >21,000 ppm without the risk of crystallization inside the evaporator at 77ºF.

5.11.2.2 Maintenance

1. Perform PMs on a routine basis. Evaluate the use of major overhauls, alternating fuel cycles, to identify and replace worn components, overhaul instrumentation, and to improve heat transfer.

> **CAUTION**: Carefully evaluate chemicals to be used to ensure cost effective treatment and/or disposal options are available. Additionally, ensure a mixed waste product will not be generated during this process. An industrial safety evaluation may be warranted.

2. Monitor heat transfer efficiencies and perform chemical cleanings on an as needed basis to improve heat transfer coefficient and reduce component activity buildup.

3. Monitor heat trace system health routinely to ensure that prolonged use has not deteriorated components or heat transfer values.

4. Install purge lines and perform periodic flushing of instrument and sample taps to preclude clogging with solids. This is particularly critical for LRW processing applications.

5. Evaluate improved materials of construction for replacement components and advanced technologies when replacing instrumentation to optimize performance.

6. If it is economically feasible to continue evaporator operation with acceptable personnel exposure, evaluate upgrading to a digital control system and installing a conductivity cell in recirculation loop. This will provide accurate live data for more accurate control.

5.11.2.3 Waste Packaging, Volume Reduction, and Disposal

1. Analyze the site structural layout to ensure concentrates packaging and transport preparation evolutions are optimized. As part of that evaluation consider alternate use of existing facilities, addition of simple, cost effective alterations, and removal of equipment "retired in place" for optimizing the use of alternate space.

> **CAUTION:** Ensure changes to packaging strategies remain in compliance with the PCP, and container C of C and procedures.

2. Analyze the disposal fee structure to define the most cost effective packaging density and activity. As part of that analysis include density and activity changes on transportation fees and packaging and disposal options.

3. When evaluating packaging requirements, include the following:
   - Container material, size, cost.
   - Density impact.
   - Dose rate.
   - Curie content.
   - VR and packaging efficiency.
   - Packaging equipment requirements.

4. Process evaporator concentrates using an advanced thermal drying process in lieu of solidification. This results in a decreased volume of solid waste and improved packaging efficiencies. Better segregation of sources would make this an even more effective treatment method. Also consider super-compacting the containers of dried bottoms to achieve additional volume reduction.

> **INDUSTRY EXPERIENCE:** At one station, their existing solidification process results in a final waste volume of 2612 cu. ft. Recent plant experience data for a similar waste stream suggests that the final solid waste volume could be reduced to approximately 726 cu. ft. by utilizing a thermal treatment process.

5.11.2.4 Exposure

1. Video tape evaporator maintenance activities. From those files, develop and use lessons learned and enhanced work practices to minimize personnel exposure.

2. Similar to the maintenance guidance, consider chemical cleaning on a periodic basis to remove activity from the system.

3. Evaluate evaporator operations and waste handling evolutions to identify potential improvements for personnel exposure reduction. As part of that evaluation, consider:
   - Frequency of operator interface with high activity components versus actual need.
   - Alternate routes for obtaining operational data.
   - The use of installed convex mirrors or remote video technology to minimize personnel entries into radiation or high radiation areas.

– Installation of remote readouts.
– The use of permanent or temporary shielding.

5.11.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

5.12 Program Element: Technologies In Development

5.12.1 Electrodeionization (EDI)

EDI with reverse osmosis pretreatment (RO/EDI) is the latest technology incorporated in new and retrofitted liquid processing systems. It has not been deployed in U.S. nuclear facilities for full scale liquid radwaste processing applications. However, this emerging technology is proven in commercial power makeup water applications, and is slated for evaluation and if appropriate, pilot testing in a nuclear application in the near future. It therefore warrants inclusion in this document.

During EDI the feedwater is first treated via reverse osmosis (RO) and then sent to EDI cells for deionization. This eliminates the need for traditional application of post RO ion exchange polishing media and the associated components and solid waste. Voltage applied across each cell forces continuous migration of contaminants out of the feedwater, through cell membranes, and into the concentrate/reject stream. The current splits the water molecules into hydrogen and hydroxyl ions, continuously regenerating the resins in the process. Unlike conventional resin beds, where quality begins to drop soon after the first regeneration cycle, the EDI resins are continuously regenerated, eliminating the need for caustic and acid regeneration chemicals.

Much of the detail associated with full scale application of this technology in a LRW process is not known, or otherwise currently available. Based on design and supplier literature it is anticipated that media throughput in gallons processed per cubic foot of media consumed should be excellent. That performance would significantly reduce the volume of solid waste traditionally generated as a result of ion exchange bead resin processing.

1. Supplemental high purity pre-filtration is required for the EDI process. Refer to the membrane section of this report and applicable references for additional detail.

2. EDI units are comprised of cells, they will require crane access for movement of new and spent cells to and from the unit.

3. When packaging spent EDI cells waste packages should be located in close proximity to the system to minimize personnel exposure and the potential for contamination spread.

5.12.2 Magnetic Molecules

Magnetic molecule technology is in the development stage and as such has not been applied to power plant process streams. However, the initial development and test results are promising, and the product is referenced here for future consideration. The development of the magnetic molecule for a proof of principle test and a patent application has been completed and additional development and testing is planned. The technology employs magnetic molecules having ferritin cores to selectively remove target contaminant ions from a solution. The magnetic molecules have a very small magnetic ferritin core and a selective ion exchange function attached to its surface. Various types of ion exchange functions can be used in the magnetic molecules, each of which is designed to remove a specific contaminant such as radioactive ions. The ion exchange functions allow the magnetic molecules to selectively absorb the contaminant ions (e.g., cobalt and cesium) from water solution while being inert to other non-target ions. The magnetic properties of the magnetic molecule allow the magnetic molecules and the absorbed contaminant ions to be removed from solution by magnetic filtration.

One process option is the sequential use of magnetic molecules with different selective groups attached. The first batch of magnetic molecules with a selectivity for a specific isotope is injected into a feed tank and thoroughly mixed by pumping around the loop with the magnets deactivated. The solution is then run through an engineered filter with the magnets activated; the magnetic molecules are held in the filter. Regenerating the filter flushes the magnetic molecules and the entrapped contamination into a final holding vessel. This action is repeated for other contaminants using an appropriate selective magnetic molecule. This approach allows complete separation of the chosen contaminants into a solution for treatment prior to disposal. This enables the bulk waste to be treated in an appropriate, cost affective manner.

5.12.3 Metal Oxide Media

One station has tested metal oxide media for antimony removal with promising results. That media is available for municipal water treatment of arsenic.

5.12.4 Centrifuge/Cyclone

This technology has proven to be effective for processing some waste streams at commercial reactor sites and for government-related projects. However, in spite of its use in Germany and in other applications, the current U.S. commercial nuclear power processing experience is insufficient to provide accurate, useful guidance on this process technology. The Korean Standard Nuclear Power Plant (KSNP) has incorporated this technology into its design however, in an effort to reduce costs and conserve space it will not be used in their next series of plants.

The large mechanically driven centrifuges will process high TDS and chemical wastes at 60 gpm, with the resultant solids routed directly to a waste package. Low TDS wastes will be treated by the centrifuge followed by an ion exchange train. One specific benefit of the centrifuge is that it requires no media to operate and therefore does not create a secondary waste stream. Additional information will be made available through EPRI as operating experience with this technology is made available.

6
BALANCE OF PLANT PROCESS SYSTEMS

6.1 Program Element: Cartridge Filters

6.1.1 Reactor Coolant

6.1.1.1 Program Impact

Reactor coolant cartridge filters are typically expensive, difficult to handle and result in personnel exposure as well as extremely poor disposal packaging efficiency. Plant evolutions, operating conditions and reactor coolant chemistry parameters can dramatically affect the size and abundance of particles in the system. The selection of and performance criteria for reactor coolant cartridges are affected by conflicting goals relative to source term control, exposure control, water chemistry quality improvements, hot particle contamination control and waste reduction.

Many PWRs have altered their reactor coolant filter pore size from 5 micron nominal in the 1970's or 2 micron absolute in the 1980's down to sub-micron filters in the 1990's.

Appropriately sized and operated sub-micron filters will reduce the source term from the primary system lowering exposure some what in containment and from the cavity. Sub-micron filters can also reduce the wear on pump seals and protect other coolant pump components. Finally, they can reduce the quantity of high activity discrete particles and thus reduce waste generation from contamination control programs.

Planned shutdown crud bursts and bypass of the letdown demineralizer for hydrazine addition during startup can result in rapid loading of these filters. Letdown cleanup system down time because of filter cartridge replacement can adversely affect exposure and source term reduction. Similarly, coolant pump cycling during fill and vent evolutions at startup, can create small crud bursts that adversely affect filter throughput and solid waste generation. Primary coolant vacuum fill techniques has proven to be an effective alternative for minimizing the concentration of crud released and hence the number of waste filters generated.

Sub-micron filters can concentrate carbon-14 that could result in increased waste generation and complicated controls in order to avoid producing greater than Class C waste. Additional coolant filters also increase the effort that must be expended to safely handle and package this high activity waste stream. Coolant cleanup system down time required to replace plugged filters can adversely affect exposure control.

6.1.1.2 Guidance

The station should evaluate, and implement as appropriate, the following program guidance:

1. Reference previous filter discussions in this document as well as the relevant chemistry guidelines.

> **CAUTION:** Glass fiber filters will catastrophically fail at 180 degrees F and will not meet most NSSS 250 degree F specifications.

2. Characterize, select and install absolute rated filters for optimal particle removal.
3. Use a stepped approach to reducing letdown filter micron size. The costs associated with cartridge procurement, system down time, spent filter handling equipment, storage and disposal can be analyzed relative to the filter pore size.
4. Use vacuum fill methods to the extent possible to minimize the volume of crud generated during primary coolant fill and vent evolutions.
5. Consider increasing the micron rating of the RCS letdown filter prior to unit shut down and start up in order to decrease radioactive solid waste generation.
6. Increasing cartridge size to a 1 or 2 micron prior to crud bursts and returning to a sub-micron cartridge when the unit is at full power is one technique to balance conflicting goals.

6.1.1.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.
2. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant”, 1989.

6.1.2 Spent Fuel Pool Skimmer

6.1.2.1 Program Impact

The primary function of the SFP skimmer is to remove surface particulate such as pollen and dust to maintain pool surface clarity. Removal of solids by the skimmer filter may also prolong the life of SFP demineralizers and filters depending on the system configuration. A second objective is to remove particulate activity. These cartridge filters are typically expensive, difficult to handle and result in an extremely poor disposal packaging efficiency.

6.1.2.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

The station should review and evaluate the objective for use of the skimmer filter. If clarity is the only concern, go to 1 below. If solids removal is required to extend the life of other media, go to number 2.

1. Pool Clarity
   - Secure the installed SFP skimmer system when not needed for refueling operations to maintain clarity so as to reduce spent filter generation.
   - Increase the particle rating for the installed filters to the largest micron size with out compromising the maintenance of surface clarity. In many cases the rating can be increased to at least 20 micron.
   - Installed skimmers may cause ripples that hamper pool clarity; in these cases, a floating skimmer saucer attachment to an underwater vacuum system may be an alternative.

2. Solids Removal
   - The input of solids into the open SFP system can result in the fouling of SFP demineralizers prior to chemical depletion. If this is experienced, the use of fine pore skimmer filters at all times may be warranted to reduce overall radwaste generation. High dirt capacity filter media will be required to increase the life of such cartridges. In general, glass media will have a higher dirt capacity than polymer and cellulose media. The micron size needed to remove dust will be 1 micron or less.

6.1.2.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.
2. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant”, 1989.

6.1.3 Spent Fuel Pool Deep Bed Prefiltration

6.1.3.1 Program Impact

This filter’s function is primarily for the prefiltration of influent to the demineralizer to preclude solids fouling of the resin. A second objective is to remove particulate activity from the SFP. These cartridge filters are typically expensive, difficult to handle and result in personnel exposure as well as an extremely poor disposal packaging efficiency. General area exposure rates from the SFP are usually due to soluble activity versus particulate activity. It is important to insure that demineralizer treatment of SFP liquid is not reduced excessively by down time required to replace this prefilter.

6.1.3.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Determine the micron rating required to insure the demineralizer depletes chemically prior to solids fouling. This may enable the micron size of the filter to be increased which will reduce spent filter generation and system down time. For highly selective organic resin, which tends to adsorb dust, this may require a filter size reduction to 1 micron or less. Reducing the filter size must be balanced with the resultant system down time to insure general area exposure rates do not increase to an unacceptable level.
2. Sub-micron coolant filters can greatly reduce hot particles and reduce waste generation from contamination control programs. Sub-micron filters also reduce the source term from the primary system lowering exposure some what in containment and from the cavity. They can also reduce the wear on pump seals and protect other coolant pump components and reduce colloidal silica in the pool.
3. Track data from routine SFP activity samples to insure pool particulate activity does not increase to an unacceptable level or adversely impact the contamination control program.

6.1.3.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant", 1989.

6.2 Program Element: Precoat Filters

6.2.1 Condensate

Condensate filtration is a complex subject that requires knowledge of system chemistry, operation, and filtration. Utility owner groups (BWR and PWR), EPRI, and others have developed comprehensive, detailed documents that address this process. It is recommended that those documents be referred to for accurate and current process guidance.

6.2.1.1 Guidance

The station should evaluate, and implement as appropriate guidance from the cross referenced documents that follow.

6.2.1.2 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.

2. EPRI. “Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations”, 1993.

3. EPRI. “Filter Demineralizer Performance Improvement Program”, 1996.

4. EPRI. "Proceedings; Second Workshop on Condensate Polishing with Powdered Resin", 1991.
5. EPRI. NP-4946-SR, "BWR Normal Water Chemistry Guidelines", 1987.
6. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant", 1989.
7. USNRC. Regulatory Guide. 1.56, "Maintenance of Water Quality in Boiling Water Reactors", Revision 1, 1978.
8. EPRI. TR-101942, "Condensate Polishing Guidelines for PWR and BWR Plants", 1993.
9. EPRI. TR-100757, "New Technology in Condensate Polishing", 1992.

6.2.2 Reactor Water Cleanup

6.2.2.1 Program Impact

A full dose precoat is utilized for reactor water cleanup (RWCU) filter/demineralizers to maximize impurity cleanup. The RWCU system has a major impact on the overall reactor coolant chemistry and therefore, the use of minimum or non precoat septa (i.e., no-to-minimal ion exchange) is currently not practiced. The precoat is typically backwashed based on activity levels frequently with remaining ion exchange capacity. This is a good practice as it minimizes the development of radioactive "hot spots" during backwash evolutions, reducing personnel exposure. Maintaining the spent media activity at lower levels can reduce waste packaging, transport and disposal costs.

Additionally, the amount of RWCU flow dictates the chemical concentration factor for the reactor vessel. Many plants have considered increasing the flowrate, but have not been able to due to regenerative/nonregenerative heat exchanger limitations and the effect on thermal performance.

The system operates at high pressure (~1,000 psi) and therefore isolation valves often leak-by creating problems during precoating. This system presents maintenance challenges. It is required during operations to maintain reactor coolant chemistry and purity and required during shutdown for crudburst cleanup and clarity. Unique strategies including on line single train outages followed by reduced duration system windows have been successfully adopted by several stations.

6.2.2.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Evaluating all goals that impact media selection and backwash criteria. Include the following in the analysis:

- Costs associated with personnel exposure, media procurement, backwash, precoat and disposal.
- Exposure associated with reduced source term, media backwash, packaging, and disposal.
- Impact of backwash frequency on reactor chemistry.

2. Evaluate plant specific maintenance schemes to maintain all components in a fully operational condition, repairing, upgrading valve components, or replacing the valves as necessary.

3. **Additional guidance is contained in the cross references identified below.**

6.2.2.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. TR 1002889, “Condensate Polishing Guidelines for Pressurized Water Reactor and Boiling Water Reactor Plants – 2004 Revision”, March 2004.
2. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.
3. EPRI. “Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations”, 1993.
4. EPRI. “Filter Demineralizer Performance Improvement Program”, 1996.
5. EPRI. “Proceedings; Second Workshop on Condensate Polishing with Powdered Resin”, 1991.
6. EPRI. NP-4946-SR, "BWR Normal Water Chemistry Guidelines”, 1987.
7. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant”, 1989.
8. USNRC. Regulatory Guide. 1.56, "Maintenance of Water Quality in Boiling Water Reactors”, Revision 1, 1978.
9. EPRI. “Preventing Biogassing in Low Level Waste”, TR-111019, 1998.

6.2.3 Spent Fuel Pool

6.2.3.1 Program Impact

The principal function of SFP purification systems is to maintain *water clarity* for underwater operations. In addition, these systems control fuel pool water *purity* and *radioactivity* associated with the storage of nuclear fuel.

This is accomplished using either precoated filter/demineralizers or a prefilter followed by deep bed demineralizer. The preference for precoated filters is consistent with the view that the *principal function* is the removal of particulate material.

The need for providing a high capacity water purification, i.e., deep bed demineralizers is viewed as unwarranted. This is based on the pools being essentially closed system where the impurities of concern originate from fuel releases and makeup water. To a great extent ionic impurities originate from the makeup water used to replace evaporation losses.

As straight forward as the purification of fuel pool water would appear, it is apparent that the industry would benefit from a reexamination of such operations. Considerable variations exist between plants in the water purification strategy being used in the operation of their fuel pools. Most precoat filters are backwashed based on dP, or less often, chemical breakthrough, precoat activity level or a combination of these factors.

In an open fuel pool the major ion exchange load is associated with carbon dioxide dissolved at the pool's surface. This innocuous dissolved gas depletes the precoat anion exchange component. However, ion exchange resin selectivity shows a decided preference for the other ionic species. Anion resin selectivity in decreasing order is as follows:

Sulfate > Nitrate > Chloride > **Bicarbonate** > Silica

(From air)

The aggressive anion species of concern to the nuclear industry (sulfate, chloride) are preferred over the air inducted bicarbonate. This means, that resin depleted by bicarbonate still retains ion exchange capacity for such ions as sulfate, nitrate and chloride. Silica on the other hand is significantly affected by the introduction of carbon dioxide (bicarbonate) to the water.

The role of silica in industry water quality standards is often misunderstood. Under the EPRI present BWR water chemistry guidelines, silica is identified as a *"diagnostic parameter.*" Monitoring this impurity is viewed as "a valuable indication of the effectiveness of the RWCU system." No chemistry "Action Level" has been established for silica because it is seen only as a diagnostic impurity.

The application of silica as a diagnostic indicator in fuel pool purification is viewed as inappropriate. The fuel pool is an aerated system and the RWCU is high temperature deaerated system. This difference can significantly alter the behavior of silica in ion exchange material. There are two principal reasons for eliminating the use of silica as a diagnostic tool for assessing fuel pool processing media depletion.

1. Silica is normally present in water in only minor concentrations. Since it is only weakly held on the ion exchange media, it becomes the first leak from the bed upon media depletion. Once silica is seen in the discharge stream, other more important ions are soon to follow. In the fuel pool case, the lag time between silica breakthrough and that of aggressive impurities (chloride, sulfate) can be significantly longer than in standard F/D operations.

2. The second reason is tied to the use of a silica containing material in new high density fuel racks. A majority of plants have expanded fuel storage capacity by replacing the original storage racks with new racks with higher fuel packing density. Many of these rack designs incorporate sheets of a silica based neutron absorber material for fuel reactivity control.

The material is a dimethyl polysiloxane polymer (silicone rubber) with boron carbide incorporated as the neutron absorber. Recent utility coupon test programs indicate unexpected gamma radiation induced changes in the material. Physical changes have been seen in the material with respect to dimensions, color, weight and elasticity.

Significant increases of silica levels in the pool water has been noted with racks using this material. For plants controlling F/Ds based on effluent silica, the impact can be significant in terms of waste generation. Where the pool purification focuses on particulate removal, silica is allowed to reach several *parts per million* and waste generation is relatively insignificant.

Silica has been effectively removed at several stations using a relatively small, simple reverse osmosis system. The silica is captured in the RO reject and routed to normal plant waste streams for subsequent process and release. At least one utility alliance has shared this equipment, increasing the overall cost effectiveness of this process option.

INDUSTRY EXPERIENCE: One BWR station allows silica to increase to 2 to 4 ppm during the operating cycle. Prior to outages they perform multiple SFP purification filter/demineralizer backwashes at 8 to 10 hour intervals to reduce silica. This eliminates high silica concentrations in liquids rejected to the condensate storage tanks.

6.2.3.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

NOTE: Segregate SFP and cavity liquids to the extent possible (e.g., don’t line up SFP demineralizer effluent to the cavity)

1. Establish water clarity as the primary purification objective. This is consistent with the industry’s accepted operating guidelines and accepted water quality standards. Water purification would be used as needed to maintain the water to an acceptable level for contamination and exposure control in the refueling area. In only the most unusual circumstances, would continuous filter/demineralization be required to control soluble ion species to acceptable limits.
2. Segregation of SFP, cavity and other liquid streams should be maintained to the maximum extent practical. Silica and other chemical species can adversely affect reactor water quality, and/or fuel integrity.
3. Evaluate the use of a silica removal membrane system for reducing silica concentrations in liquids to acceptable levels.

6.2.3.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.
2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.
3. EPRI. "Filter Demineralizer Performance Improvement Program", 1996.
4. EPRI. "Proceedings; Second Workshop on Condensate Polishing with Powdered Resin", 1991.

6.3 Program Element: Non and Minimum Precoat Filters

6.3.1 Condensate

Condensate filtration and ion exchange is a complex subject that requires knowledge of system chemistry, operation, and filtration. Utility owner groups (BWR and PWR), EPRI, and others have developed comprehensive, detailed documents that address this process. It is recommended that those documents and organizations be referred to for accurate and current process guidance.

6.3.1.1 Guidance

The station should evaluate, and implement as appropriate guidance from the cross referenced documents that follow.

6.3.1.2 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. TR 1002889, "Condensate Polishing Guidelines for Pressurized Water Reactor and Boiling Water Reactor Plants – 2004 Revision", March 2004.
2. EPRI. "Filter Demineralizer Performance Improvement Program", 1996.

6.4 Program Element: Condensate System Prefiltration

6.4.1 Program Impact

Condensate prefiltration is a complex subject that requires knowledge of system chemistry, operation, and filtration. The use of pre-filters for the Condensate Deep Bed Demineralizers (CDD) results in less iron transport to the downstream deep bed condensate polisher minimizing dP buildup. In BWR's this results in elimination or minimization of the need for resin cleaning, a process that typically generates between 15,000 and 30,000 gallons of waste liquid, with some stations generating > 45,000 gallons per URC.

While it is clear that prefiltration results in a positive affect on overall plant performance, it has produced a significant challenge to RW processing operations at the majority of stations employing this technology. The prefilter backwash waste water is typically routed to a phase separator or tank for settling. Industry experience has clearly indicated that in the majority of instances, the iron does not settle without the aid of chemical additives such as copolymers or other flocculants.

> **INDUSTRY EXPERIENCE:** _A two unit site's condensate polishing system was retro-fitted with pleated non-precoat filters upstream of the existing deep bed polishing ion exchangers. This resulted in a significant reduction in the solids challenge to ion exchange media and eliminated the need for URC. However, the filter backwash presented a severe challenge to the LRW system.
>
> The contents of the filter backwash receiving tanks are transferred to condensate phase separators. After settling, the upper (liquid) portion of the phase separator is decanted to the LRW collection tank. The lower portion is allowed to accumulate solids until it is economical to process the solids into a HIC for disposal. The smaller iron oxide particles, no longer combined with spent media, were not settling in the phase separators. This heavy loading of small particles was severely challenging the LRW carbon and cartridge filters, and ultimately HIC dewatering laterals.
>
> Initially, the LRW system was producing recycle quality water, but resin usage due to the new solids challenge was ~25% higher. Chemistry samples for jar testing were taken from the discharge side of the phase separator sludge pumps and decant samples. Test resin columns using activated carbon and ion exchange media were used to evaluate the effects of chemical additives.
>
> The most consistent results were obtained using a commercially available polymer with NaOH addition for pH control. Polymer and caustic, followed by a demineralized water rinse, were pumped into the phase separator. The LRW system media throughput improved following this chemical pretreatment enhancement.

The resultant sludge product has also created challenges for transfer from the phase separation vessel to a waste sludge tank and/or waste container. Finally, those transfer operations also create a sluice and/or decant waste stream that again is laden with iron, creating additional dewatering and subsequent LRW processing challenges.

6.4.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Perform a detailed, comprehensive benchmark of plants that have employed this technology.
2. The prefilter design should consider the following:
   - Backwash liquid waste volume minimization
   - Phase separation options

- Accurate, multi-phase (liquid/solid) level indicators for phase separation and sludge vessels
- Conical bottom vessels for phase separation for efficient sludge removal evolutions
- Phase separation vessel chemical addition and high energy mixing configurations
- Sludge transfer minimization – backwash receiver/phase separation directly to waste containers, bypassing waste sludge tanks.
- Additional waste container processing shields/bays to accommodate extended pre-shipment dewatering cycles.

3. Waste containers should be carefully evaluated to ensure that dewatering material surface area and mesh size are optimized. Consider the use of in container backwashable candle filters for concentrating this waste stream.

4. The station should periodically perform a mass balance for iron to reconcile prefilter influent concentrations and processed liquid volume, backwash concentrations and liquid volume, phase separation solid volumes, and packaged waste volumes.

5. Utility owner groups (BWR and PWR), EPRI, and others have developed comprehensive, detailed documents that address this process. In addition to the documents cross referenced in this section of the document, it is recommended that those documents and organizations be referred to for accurate and current process guidance.

6.4.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. TR 1002889, “Condensate Polishing Guidelines for Pressurized Water Reactor and Boiling Water Reactor Plants – 2004 Revision”, March 2004.
2. USNRC. Regulatory Guide. 1.56, "Maintenance of Water Quality in Boiling Water Reactors”, Revision 1, 1978.

6.5 Program Element: Deep Bed Demineralizers

6.5.1 Condensate

Ion exchange for condensate systems is a complex subject that requires extensive knowledge of system chemistry, operation, and ion exchange media and dynamics. Utility owner groups (BWR and PWR), EPRI, and others have developed comprehensive, detailed documents that address this process. It is recommended that those documents be referred to for accurate and current process guidance.

6.5.1.1 Guidance

The station should evaluate, and implement as appropriate guidance from the cross referenced documents that follow.

6.5.1.2 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. TR 1002889, "Condensate Polishing Guidelines for Pressurized Water Reactor and Boiling Water Reactor Plants – 2004 Revision", March 2004.
2. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.
3. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.
4. EPRI. NP-4946-SR, "BWR Normal Water Chemistry Guidelines", 1987.
5. USNRC. Regulatory Guide. 1.56, "Maintenance of Water Quality in Boiling Water Reactors", Revision 1, 1978.

6.5.2 Reactor Letdown and Reactor Water Cleanup

6.5.2.1 Program Impact

Deep bed ion exchangers, used in all domestic PWR stations for reactor coolant letdown demineralization, are utilized in very few BWR plants. This is primarily because of the significant plant thermal loss associated with cooling the purification stream to obtain a desired BWR flow rate of 1,000 gpm. Cleanup beds are typically removed from service on conductivity, chlorides or nuclide break. The spent media is very high in activity, which makes packaging, transportation and disposal costly.

The replacement of these beds immediately after depletion can adversely affect the exposure control program and input high activity and high particulate sluice water into the liquid radwaste system. Such liquids may be difficult to process and can adversely affect liquid effluents. Holding a depleted bed in the vessel for radioactive decay prior to replacement can reduce the impact on the liquid radwaste system and the exposure control program. Such decay may also reduce disposal fees.

Boron Thermal Regeneration System (BTRS) is a radioactive demineralizer design concept that allows in-situ resin regeneration and reuse. The demineralizer is "regenerated" by flushing the bed with heated water. The system then removes boron by chilling the water to 45 degrees F before directing it through the demineralizer bed. BTRS was originally designed to alternately remove and add boron to the RCS as necessary to increase or reduce power during load following evolutions. Most nuclear plants are base loaded at 100%, therefore the plants with this capability use BTRS only to help in removing boron as the reactor core approached the end of its useful life. As boron concentrations approach single digits it becomes necessary to utilize a

BTRS bed containing new resin since it is extremely difficult to achieve a "thermal regeneration" to these low levels.

> **INDUSTRY EXPERIENCE:** One station has been able to achieve "coast-down" using thermally regenerated beds twice previously; however, because of the higher cost of replacement power the station normally loaded new resin to insure they were able to operate at 100% power for as long as possible.
>
> That station also approved a change to achieve "zero" boron (defined as 5 PPM) utilizing only thermally regenerated beds. That approach resulted in saving $13,500 in resin replacement costs and avoided radwaste disposal costs of $80,000 to $90,000.

6.5.2.2 Guidance

The station should evaluate and implement as appropriate, the following program guidance:

1. Refer to ion exchange section of this document for information regarding waste handling, loading logic, and disposal.

2. Determine the reason for bed replacement. Cation capacity or anion capacity depletion may be the cause for replacement. Evaluate whether the reason for replacement changes from one bed to the next.

3. Consider an alternate supplier of resin. Organic resin from one vendor may have a higher capacity for soluble species than what is currently in use.

> **CAUTION:** The station should carefully review UFSAR, Licensing documents and safe shutdown requirements prior to altering resin ratios to ensure regulatory compliance. The use of a 10CFR50.59 evaluation may be required or prudent to document procedural and regulatory compliance.

4. If the cause for bed replacement is inconsistent, consider altering the ratio of cation to anion as appropriate. Any change in the resin ratio must be evaluated for impact on design basis documents and safe shutdown requirements.

5. If the expensive lithiated letdown bed is always replaced because of shutdown crud bursts, consider a separate bed to cleanup the crud burst. An inexpensive non-lithiated mixed bed, possibly with a high cation load, can be used for shutdown service, preserving and extending the life of the lithiated mixed bed. Many plants have implemented this practice. This practice also enables decay of the shutdown bed for a full fuel cycle prior to replacement. However, multiple vessels must be available in the letdown system (e.g., three or more) to implement this practice.

6. If multiple vessels are available in the cleanup system, consider segregated loading of cation and anion resin. RCS cleanup would be provided by aligning the cation and anion vessels in series. Such a change must be evaluated for impact on design basis documents and safe shutdown requirements. Segregated loading enables low dose spent anion resin to be disposed of separately from high activity cation resin, greatly reducing cost. Off-site volume reduction of anion resin is possible, further reducing the disposal cost.

7. When evaluating packaging requirements, include the following:
   - Container material, size, cost.
   - Density impact.
   - Curie content.
   - Dose rate.
   - VR and packaging efficiency.
   - Packaging equipment requirements.

6.5.2.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, “Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste”, V3P1, 1994.
2. EPRI. “Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations”, 1993.
3. EPRI. NP-4946-SR, "BWR Normal Water Chemistry Guidelines”, 1987.
4. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant”, 1989.
5. USNRC. Regulatory Guide. 1.56, "Maintenance of Water Quality in Boiling Water Reactors”, Revision 1, 1978.
6. EPRI. TR-109444, “Analysis of Advanced Liquid Waste Minimization Techniques at a PWR: Advanced Media, Pleated Filters, and Economic Evaluation Tools”, March 1998.

6.5.3 Spent Fuel Pool

6.5.3.1 Program Impact

The function of this bed is to provide proper water chemistry and clarity for the safe storage of fuel for reuse and safe long term storage of spent fuel. A second objective is to insure general area exposure rates do not increase to an unacceptable level. The use of a deep bed supports the view that water purification, to limit corrosion of the fuel, and removal of nuclides from potentially failed fuel elements are the principal functions.

For deep beds the change out criteria varies through out the industry. The break through of chloride, fluoride or sulfate and nuclides are most often used. However, pH and silica break through are used at other plants.

If exposure control is a concern, the deep bed will need to be aligned for SFP cleanup more often. In such situations, the spent media may be high in activity making packaging, transportation and disposal costly. Since most pools are provided with only one vessel, the replacement of such beds must be performed immediately. This requirement eliminates any possibility of radioactive decay to reduce the impact of high activity sluice water on the liquid radwaste system. In such situations, removal of radioactive particles from the SFP via installed cartridge filters or under water vacuum filters may be preferable to collecting particulate on resin which will be liberated during the replacement of the bed.

If proper water chemistry for fuel storage is the major concern, the strategy for water purification should be carefully reviewed. In an open pool the major ion exchange load is associated with carbon dioxide dissolved at the pool's surface. This innocuous dissolved gas depletes the anion resin. However, ion exchange resin selectivity shows a decided preference for the other ionic species. Anion resin selectivity in decreasing order is as follows:

Sulfate > Nitrate > Chloride > **Bicarbonate** > Silica

(From air)

The aggressive anion species of concern to the nuclear industry (sulfate, chloride) are preferred over the air inducted bicarbonate. This means, that resin depleted by bicarbonate still retains ion exchange capacity for such ions as sulfate, nitrate and chloride. Silica on the other hand is significantly affected by the introduction of carbon dioxide (bicarbonate) to the water.

The role of silica in industry water quality standards is often misunderstood. Under the EPRI present BWR water chemistry guidelines, silica is identified as a *"diagnostic parameter."* Monitoring this impurity is viewed as "a valuable indication of the effectiveness of the RWCU system." No chemistry "Action Level" has been established for silica, since it is seen only as a diagnostic impurity. It should be noted, that EPRI is presently investigating the effect of silica on fuel cladding corrosion. The data gathered to date are inconclusive as to the role of silica in fuel cladding corrosion.

The application of silica as a diagnostic indicator in fuel pool purification is viewed as inappropriate. The fuel pool is an aerated system and the RWCU is high temperature deaerated system. This difference can significantly alter the behavior of silica in an ion exchange bed. There are two principal reasons for eliminating the use of silica as a diagnostic tool for assessing fuel pool resin depletion.

1. Silica is normally present in water in only minor concentrations. Since it is only weakly held on the ion exchange resin, it becomes the first leak from the bed upon resin depletion. Once silica is seen in the discharge stream, other more important ions are soon to follow. In the fuel pool case, the lag time between silica breakthrough and that of aggressive impurities (chloride, sulfate) can be significantly longer than in standard demineralizer operations.

2. A majority of plants have expanded fuel storage capacity by replacing the original storage racks with new racks with higher fuel packing density. Many of these rack designs incorporate sheets of a silica based neutron absorber material for fuel reactivity control.

The material is a dimethyl polysiloxane polymer (silicone rubber) with boron carbide incorporated as the neutron absorber. Recent utility coupon test programs indicate unexpected gamma radiation induced changes in the material. Physical changes have been seen in the material with respect to dimensions, color, weight and elasticity.

Significant increases of silica levels in the pool water have been noted with racks using this material. For plants controlling demineralizers based on effluent silica, the impact can be significant in terms of waste generation. Where the pool purification focuses on particulate removal, silica is allowed to reach several parts per million and waste generation is relatively insignificant.

Silica has been effectively removed at several stations using a relatively small, simple reverse osmosis system. The silica is captured in the RO reject and routed to normal plant waste streams for subsequent process and release. At least one utility alliance has shared this equipment, increasing the overall cost effectiveness of this process option.

6.5.3.2 Guidance

The station should evaluate, and implement as appropriate, the following program enhancement guidance:

1. Consider adopting water clarity as the primary purification objective. This is consistent with industry's accepted operating guidelines and accepted water quality standards. Such a change must be evaluated for impact of design basis documents and fuel vendor specifications.
   - Water purification should be used as needed to maintain an acceptable general area exposure rate near the pool or to maintain the contamination control program. Placing the system in service only as required will reduce radwaste generation.
   - Consider an alternate supplier of resin. Organic resin from one vendor may have a higher capacity for soluble species than what is currently in use.
   - If sulfates or anions are not an issue, consider increasing the ratio of cation to anion in the bed.

2. If cation resin breaks down, as noted by sulfate effluent or fouling of resin filters, (due to H_2O_2 formation in the SFP) prior to chemical exhaustion, consider a stochiometric bed. A 15 ft^3 bed may last one fuel cycle.

> **INDUSTRY EXPERIENCE:** A 3:1 cation to anion volumetric ratio has been used successfully to extend the life of SFP beds to two years in continuous service.

– Eliminating silica as a demineralizer control limit. Water clarity and control of aggressive ions, e.g., sulfate, chloride and nitrate, are the principal changeout parameters. Silica would not be used to determine replacement of ion exchange resin. Resin change out would be based on chloride, nitrate or sulfate breakthrough.

INDUSTRY EXPERIENCE: One BWR modified their operating strategy for the fuel pool purification system. The system consisted of an etched disc filter followed by a deep bed demineralizer. The demineralizer contains 90 ft^3 of ion exchange resin with an anion to cation ratio of 2 to 1. Throughout the plant's operating life, the replacement of demineralizer ion exchange resin was based on maintaining the effluent silica <100 ppb and conductivity <1µS/cm. The plant had earlier installed new high density fuel racks incorporating boron carbide silicate absorbers. The combination of chemical control limits and the silicate absorber resulted in demineralizer resin bed replacement every 50 days. This generated 650 ft^3 annually of spent resin, representing an operating cost of $390,000 per year for resin disposal and replacement.

Under the new strategy, silica was eliminated as a demineralizer control limit. Water clarity and control of aggressive ions, e.g., sulfate, chloride and nitrate, became the principal control parameters.

Implementation of the new operating philosophy reduced the fuel pool waste generation from 650 ft^3 to 90 ft^3 per year. This represented an operating cost savings of $330,000. Over the remaining life of the plant, the new program is estimated to save the utility $5,900,000. Key data taken from a 330 day demineralizer service run is presented in the figures below.

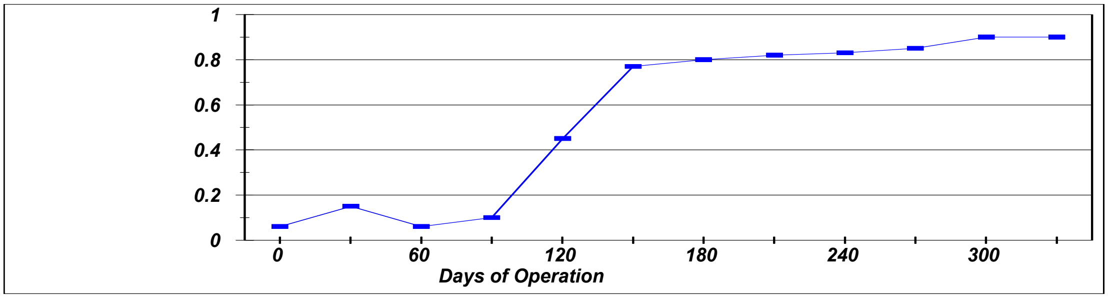

Figure 6-1
Demineralizer Effluent Conductivity µS/cm

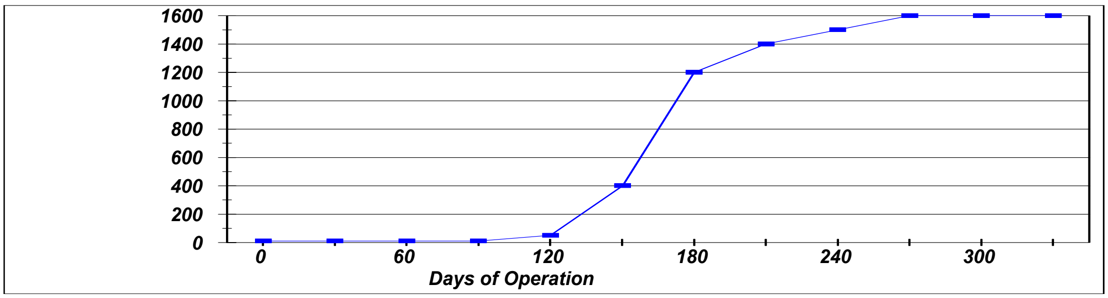

Figure 6-2
Demineralizer Effluent Silica ppb

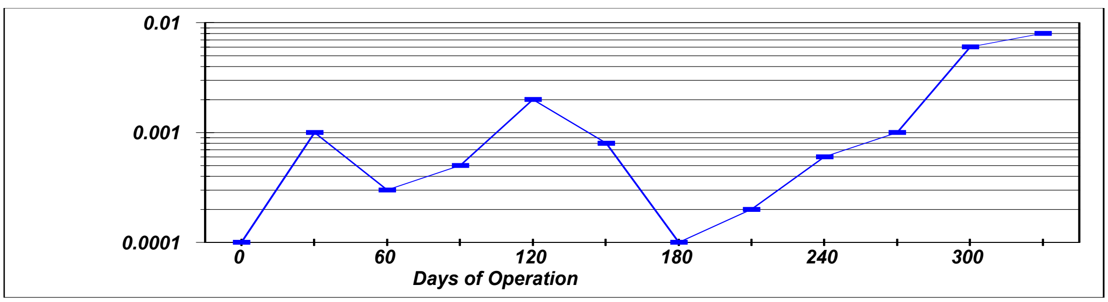

Figure 6-3
Fuel Pool Activity µci/ml

Note that the demineralizer effluent break through for silica and conductivity was experienced at 90 to 120 days. At the end of the service run, the conductivity was 0.9 µS/cm and the silica was approximately 1,600 ppb. During the major portion of the cycle the fuel pool activity fluctuated in the range of 1 E-04 to 1 E-03. At the end of the service run the pool water activity had reached a value of 8 E-3. Throughout the service run aggressive ions were maintained below their control limit of <100 ppb.

- Eliminate the use of full time demineralization, using it only as necessary to control aggressive ion impurities to acceptable levels.
- Operate the fuel pool filter as required to maintain water clarity.

6.5.3.3 Cross Reference(s):

Appendix A - Reference(s):

1. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.
2. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.
3. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant", 1989.

A
CROSS REFERENCES TO OTHER RESOURCES

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2. EPRI. NP-7386-V41995, “Radwaste Desk Reference Volume 4: Mixed Waste”.
3. EPRI. “Filter Demineralizer Performance Improvement Program”, 1996.
4. EPRI. “Proceedings; Second Workshop on Condensate Polishing with Powdered Resin”, 1991.
5. EPRI. “Preventing Biogassing in Low Level Waste”, TR-111019, 1998.
6. EPRI. NP-4946-SR, "BWR Normal Water Chemistry Guidelines”, 1987.
7. EPRI. NP-6640, "The Nature and Behavior of Particulates in PWR Primary Coolant”, 1989.
8. EPRI. TR-109444, “Analysis of Advanced Liquid Waste Minimization Techniques at a PWR: Advanced Media, Pleated Filters, and Economic Evaluation Tools”, March 1998.
9. EPRI. TR-105901, “Spent Resin Disposition-Available Alternatives and Selection Analysis”, 1995.
10. EPRI. TR-106928, “Liquid Waste Processing at Comanche Peak”, 1996.
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12. EPRI. TR-105569, "Liquid Radwaste Minimization Where we were, where we are, where we are going", Proceedings EPRI International Low-Level Waste Conference, Orlando, Fl., 1995.
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17. EPRI. NP-7309, "EPRI Guide to Managing Nuclear Utility Protective Clothing Programs", 1991.

18. EPRI. RS-107201, "Low Level Waste Characterization Guidelines", 1997.

19. EPRI. "Radioactive Colloid Removal by Optimizing Chemical Parameters, Phase II – Media Testing", 2001.

20. EPRI. TR-1009566, "Non-Metal Filter Study", November 2004.

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22. EPRI. TR-1009558, "Evaluation of an Alternate, Advanced Filtration Media for Radioactive Liquid Processing", August 2004.

23. EPRI. TR-114751, Improved Cobalt Removal, Palo Alto, CA., 2000.

24. EPRI. NP-7386, "Radwaste Desk Reference, Volume 3 Part 1: Processing Liquid Waste", V3P1, 1994.

25. EPRI. "Sourcebook on Ion Exchange for Liquid Radwaste Treatment - Materials, Systems and Operations", 1993.

26. EPRI. Waste Logic™ software programs and user manuals.

27. EPRI RadBench Website

28. EPRI. TR-105859, "Cost Effective Liquid Processing Programs", 1995.

29. EPRI. TR-1008129, "EPRI ALWR Project: Utility Position Paper on Significant Design Considerations for the Westinghouse AP1000 LLW Management Program", December 2004.

30. EPRI. TR-1008128, "Development of the EPRI Magnetic Molecules Technology", October 2004.

31. EPRI. TR-1008016, "EPRI ALWR Project: Review of Westinghouse AP1000 LLW Management Program", November 2003.

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50. EPRI. TR-106780, "EPRI Advanced Light Water Reactor Utility Requirements Document, Volumes I, II, & III, Revisions vary by Chapter", 1999. (Most applicable document is Volume 3, Revision 7, V3R7.)

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53. EPRI. NP-7386-V3P2, “Radwaste Desk Reference: Volume 3, Parts 1 and 2”, May 1994.

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B
RADWASTE PROGRAM IMPACT AWARENESS

The following pull-out sections are for use by LRW program managers. They are designed to be used as tools for increasing station department manager's knowledge of their program's impact on LRW processing.

Organization: Senior Management

Objective	Reference Section
1. Visible management support.	1.2, 2.4, 2.5, 2.8
♦ Clear and challenging goals and objectives.	
◊ Benchmark performance.	2.3, 2.4
◊ Station goals.	2.2, 2.5, 2.9
◊ Integrate goals between station organizations.	2.5
◊ Communicate goals to station personnel.	2.3, 2.7, 2.5, 4.7
2. Front end management.	
♦ Work/outage planning.	2.9, 3.5, 4.7
♦ Aggressive leak control program.	3.2, 3.4
♦ Aggressive waste segregation program.	3.3, 3.8, 4.3, 4.5, 4.6
♦ Good housekeeping.	2.11
♦ Source term reduction.	2.12
3. Comprehensive performance monitoring program.	
♦ Equipment performance.	2.3, 2.11
♦ Goals.	2.2, 2.3, 2.4
♦ Key support programs (work/outage planning, leak reduction, housekeeping).	2.11, 3.4, 3.5, 4.7
♦ Source term reduction.	2.12

Organization: Station Management

Objective	Reference Section
1. Evaluate station goals relative to liquid processing.	2.2, 2.5
2. Station awareness.	2.7, 2.5
♦ Communication and support.	
◊ Verbal.	
◊ Written.	
◊ Visual.	
♦ Goal review with other organizations.	
3. Program costs.	2.6, 2.4
♦ Liquid radwaste processing.	
♦ Wet radwaste packaging and disposal.	
♦ Impact on resources.	
♦ Industry organization impact.	
4. Corporate interface and support.	2.4, 2.5
5. Feedback mechanism.	2.3, 2.4, 2.7, 4.7

Organization: Maintenance

Objective	Reference Section
1. Evaluate goals potentially impacting liquid processing.	2.2, 2.5, 2.9
2. Training.	2.8
♦ Initial trade/craft specific session.	
♦ Brief annual refresher tied to routine trade specific sessions.	
♦ Video.	
3. Liquid influent quantity.	3
♦ Leak repair prioritization.	3.4
◊ Design seal leak-off versus actual and affect of run-in.	
◊ Live load packing.	
◊ Improved pump seals - particularly applicable to acid and caustic systems.	
♦ System draining.	3.2, 3.3, 3.5, 3.8, 3.10, 4.3
4. Impact of “reworks”.	3.4
5. Liquid influent quality.	4
♦ Oil and hydraulic fluid addition and changeout.	4.10
♦ Chemical solvents and cleaners.	4.2
♦ Precipitation and groundwater.	4.12
6. Feedback mechanism.	2.3, 2.4, 2.7, 4.7

Organization: Operations

Objective		Reference Section
1.	Evaluate goals potentially impacting liquid processing.	3.2, 3.5, 3.9
2.	Training.	2.8
♦	Initial session.	
♦	Brief annual refresher tied to routine training sessions.	
♦	Video.	
3.	Liquid influent quantity.	4
4.	Leak identification and repair prioritization.	3.4
5.	Design seal leak-off versus actual and affect of run-in.	2.9, 3.4
♦	System draining.	2.9, 2.10, 3.10, 4.3
♦	Liquid processing system media handling.	4.8
♦	Identifying influent perturbations.	3.2
♦	System flushing.	4.3, 4.8, 4.9
6.	Liquid influent quality.	4
♦	Oil and hydraulic fluid addition.	4.10
♦	Waste liquid processing media handling.	4.8
♦	Chemical solvents and cleaners.	4.2
♦	Closed cooling and fire protection system draining.	3.3, 3.10
♦	Identifying influent perturbations.	3.2, 4.4
♦	System flushing.	4.3, 4.8, 4.9
7.	Feedback mechanism.	2.3, 2.4, 2.7, 4.7

Organization: Chemistry

Objective		Reference Section
1.	Evaluate goals potentially impacting liquid processing.	2.2, 2.5, 2.9
2.	Training.	2.8
♦	Initial session.	
♦	Brief annual refresher tied to routine training sessions.	
♦	Video.	
3.	Liquid influent quantity.	3.9
♦	Sample sink waste disposition.	
♦	Sample lab waste disposition.	
♦	Use of sample lab sinks and small demineralized water units.	
♦	Liquid processing media rinsing and flushing.	
♦	Liquid waste effluent release and recycle criteria impact and evaluation.	
4.	Liquid influent quality.	4
♦	Chemical analysis waste and alternative analytical procedures.	4.15
♦	Chemical control program - evaluation of impact on liquid processing media and operations.	4.2
♦	Influent characterization.	4.4
5.	Feedback mechanism.	2.3, 2.4, 2.7, 4.7

Organization: Training

Objective	Reference Section
1. Use of organization/trade specific liquid radwaste impact training modules.	2.8
♦ Tied to specific tasks or evolutions.	
2. Developing and implementing the use of a generic video for non radwaste organizations.	2.8
3. Review of radwaste processing operations for potential system operator training enhancements.	2.3, 2.4, 2.7, 3.7, 4.7
4. Qualification program maintenance.	2.8
♦ Plant organization input.	2.4, 2.5
♦ Equipment/material vendor input to optimize performance.	
5. Feedback mechanism.	2.3, 2.4, 2.7, 4.7

Organization: Radiation Protection

Objective	Reference Section
1. Evaluate goals potentially impacting liquid processing.	2.2, 2.5, 2.9
2. Training.	2.8
♦ Initial session.	
♦ Brief annual refresher tied to routine training sessions.	
♦ Video.	
3. Liquid influent quantity.	3
♦ Identification of leaking components.	3.2, 3.4
♦ ALARA line and component flushing.	4.3, 4.14
♦ Use of alternates to processing.	3.8
♦ Spent liquid waste processing media sluice evolutions/line flushing.	3.7
4. Liquid influent quality.	4
♦ Use and maintenance of drain socks.	4.3
♦ Identification of influent perturbations.	3.2, 4.4
5. Solid waste generation.	
♦ Dose rate limitations on liquid waste processing media changeout versus cost benefit analysis.	2.12, 5, 6
6. Feedback mechanism.	2.3, 2.4, 2.7, 4.7

C
SELECTION OF "BEST" TRACKING, TRENDING AND PERFORMANCE MONITORING CONCEPTS

Individual stations have specific requirements and reasons for tracking program data, therefore this appendix does not attempt to represent a recommended reporting format. It contains a compilation of the "best" segments of liquid waste processing reports from numerous stations. It is intended to illustrate varying strategies for tracking, trending, and reporting liquid waste program statistics. The LRW program manager should review the following material and use it to enhance existing tracking and trending programs, ensuring sufficient data is tracked and trended to effectively monitor the program status.

It is equally important to consider the target audience that will be using the data in routine status reports or posted graphics. When developing the material, consider:

- The amount of detail versus required knowledge.
- The units of expression and user familiarity.
- Volume of data presented.
- Data labeled with corresponding date and time.
- Acronyms defined in key.
- Graphic representation of data.
  - Clear delineation or annotation of desired performance.
  - Adequacy of scale and labels.
  - Bar and segment schemes - ability to reproduce in black and white versus colored.

D
GLOSSARY OF FILTRATION TERMS

Absolute Micrometer Rating -- The diameter of the largest solid particle which a specified filter media will pass.

Actuation Pressure --A pressure setting at which a ΔP indicator actuates a signal device indicating that a pre-determined differential pressure has been sensed.

Bar-- A unit of pressure. One(l) Bar = 14.5 PSI.

Beta Ratio -- The ratio of the number of particles greater than a specified micrometer in the influent fluid to the number of particles larger than the specified micrometer in the effluent fluid when calibrated to specific test conditions. (See Filter Application Guide-- Multi-Pass Test.)

Bubble Point-The differential gas pressure which when applied to a filter element submerged near the surface of a test fluid causes the first steady emission of gas bubbles from the filter element.

Center Tube -- A support device designed to support the filter media in a filter element while permitting fluid flow and resisting element collapse to a predetermined differential pressure.

Cleanable Filter Element-- A filter element which upon reaching a predetermined level of contaminant (determined by differential pressure) can be cleaned to an acceptable level of performance for re-use in its fluid system. (Note: There is usually a maximum number of times specified for re-cleaning and re-use.)

Collapse Pressure -- The minimum differential pressure which a filter element will withstand without permanent deformation.

Contaminant Capacity -- The resultant weight (usually in grams) of an artificial contaminant (usually A-C fine test dust) which when added at specified intervals and at a specific flow rate produces a differential pressure across a filter element which can be converted or related to the useful life of a filter element (usually expressed in hours).

Depth Type Filtration -- A filter medium which primarily retains contaminant within tortuous passages.

Disposable Filter Element-- A filter element which is not recleanable and is therefore discarded and replaced at the end of its useful life. (Sometimes referred to as a throwaway or non-cleanable element.)

Edge Type Filtration-- A filter medium whose passages are formed by the adjacent surfaces of stacked discs, edge wound ribbons, or single layer filament.

Effective Filtration Area That area of the fluid medium in a filter element which is exposed to flow.

Efficiency-- The ability of a filter element to remove/retain a specific artificial contaminant in a specified concentration under controlled test conditions. Efficiency is expressed in percent. (See Filter Application Guide -- Degree of Filtration and Multi-Pass Test.) Effluent -- The fluid leaving a component after having passed through the mechanism of the component.

Filter Assembly-- A filtering device consisting of a housing, case, seals, and filter element which directs flow from an inlet port, through a filter element and through an outlet port, and in so doing reduces fluid contamination.

Filter Element- A porous device which performs the actual filtration process.

Filtration --The process of separating insoluble particulate matter from a gas or fluid by passing the fluid through a filter medium which allows only particulate of a predetermined size to pass while removing/retaining particulate matter greater in micrometers than the predetermined size.

Flow Fatigue Resistance-- The ability of a filter medium to resist structural failure or deterioration from cyclic loading.

Fluid Compatibility --The appropriateness of using the materials of a filter assembly, filter element or seal in conjunction with a specified fluid.

Full Flow Filter -- A filter which filters all influent flow.

Influent-- The fluid entering a component.

In-line Filter-- A filter assembly in which the inlet, outlet, and filter element axes are in a straight line.

L-Type Filter-- A filter assembly in which the inlet and outlet ports are positioned at 90 degrees to each other.

Mean Filtration Rating-- A measurement of the average pore size of a specific filter medium.

Media Migration -- Separation and/or deterioration of components of the filter medium and subsequent release into the effluent. (Often caused by flow fatigue; see above.)

Medium --The porous material that performs the actual process of filtration (usually referred to in terms of its plural; media).

Micrometer(m)--A unit of length. A micrometer is one millionth of a meter or 0.000039" (39 millionth's of an inch). Expressed in convenient terms-- 25 micrometers are approximately equal to one thousandth of an inch (.001").

Multi-Pass Test --· A test used to determine the Beta ratio of a filter element.

Nominal Filtration Rating--An arbitrary micrometer value established by a filter manufacturer as a relative indication of average filtration capability.

Partial Flow Filter -- A filter which filters only a portion of the influent flow.

Pascal/Kilopascal (kPa)- A unit of pressure (Kilopascal Preferred). One(l) kPa = 6.895 PSI.

Permeability -- The relationship of flow per unit area to differential pressure across a filter medium.

Pore -- A small channel or opening in a filter medium which allows passage of fluid.

Pore Size Distribution -- The ratio of the number of holes of a given size to the total number of holes per unit area expressed as a percent and as a function of hole size.

Porosity--The ratio of pore volume to total volume of a filter medium expressed as a percent.

PSIA -- Pounds per square inch absolute = PS1G (Gage) + atmospheric pressure (14.696).

PSID(P)-- Pounds per square inch differential.

PSIG-- Pounds per square inch gage = PSIA minus atmospheric pressure (14.696).

Rated Flow -- The optimum flow rate for which a filter is designed.

SideSeal --The longitudinal seam joint of a convoluted filter element pack.

Strainer--A coarse or more open filter element usually greater than 50 µm.

Surface Type Filtration -- A filter medium which primarily retains contaminant on the influent face.

System Silting -- The agglomeration and settling of ultrafine particles in a fluid system.

T-Type Filter-- A filter assembly in which the inlet and outlet ports are on opposite ends of a common axis and with the filter element axis perpendicular to that common axis.

Unloading -- The release or washing through of contaminant which was previously trapped or retained by the filter medium.

Wash Filter--A filter in which a larger unfiltered quantity of fluid flowing parallel to the filter element axis is utilized to continuously clean the influent surface which filters the lesser flow.

E
GLOSSARY OF ABBREVIATIONS AND ACRONYMS

10CFR61	Code of Federal Regulations, Title 10, Part 61. Contains regulations related to waste characterization, classification and disposal.
ALARA	As Low As Reasonably Achievable. A concept to reduce personnel exposure to the lowest practical levels.
ANI	American Nuclear Insurers.
BWR	Boiling water reactor.
CCW	Component/closed cooling water.
CFD	Condensate filter demineralizer.
C of C	Certificate of Compliance
CST	Condensate storage tank.
Cu. Ft.	Cubic feet.
DAW	Dry active waste.
DE	Diatomaceous earth
DF	Decontamination factor. Typically determined by comparing a LRW stream process or component's influent activity to effluent activity.
dP	Differential pressure/delta pressure.
F/D	Filter demineralizer.
UFSAR	Updated final safety Analysis Report.
HIC	High integrity container.
HVAC	Heating, ventilation and air conditioning.
INPO	Institute for Nuclear Power Operations.
LLD	Lower limit of detection.

LOCA Loss of coolant accident.

LRW Liquid radwaste. Typically floor drains in PWR stations and floor and equipment drains in BWR stations. In some PWRs, this waste stream would include reactor letdown waste.

MDA Minimum detectable activity

NEI Nuclear Energy Institute.

NPDES National Pollution Discharge Elimination System

USNRC U.S. Nuclear Regulatory Commission.

O&M Operations and Maintenance. The base budget for normal plant evolutions.

PCP Process Control Program.

PM Preventative maintenance.

PWR Pressurized water reactor.

RCA Radiologically controlled area.

RCS Reactor coolant system.

RW Radioactive waste.

RWCU Reactor water cleanup. The primary reactor coolant purification system in BWR stations.

SFP Spent fuel pool.

S/G Steam generator.

SGBD Steam generator blowdown. A system designed for removing impurities from the secondary side of PWR steam generators.

TRU Transuranic.

URC Ultrasonic resin cleaner. A system that employs ultrasonic waves and hydraulic separation to clean bead resin.

VR Volume reduction. Typically calculated by comparing pre and post processing volumes in Cu. Ft.

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